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STUDIES AND INVESTIGATIONS OF THE FATE AND EFFECT OF THE SHELL OIL SPILL, PLATFORM B, BLOCK 26, SOUTH TIMBALIER BAY (DECEMBER 1, 1970 - NOVEMBER 30, 1971)

RESOURCES TECHNOLOGY CORPORATION,
HOUSTON, TEXAS

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY,
WASHINGTON, D.C.

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Prepared For:

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Washington, D.C.

Prepared by:

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E.A Review Notice

This report has been reviewed by the Water Quality Office, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FORWORD

Under the provisions of Sections 11 and 12 of the Federal Water Quality Improvement Act of 1970 (PL 91 224) and Presidential Executive Order 11548, dated July 20, 1970, the United States Environmental Protection is charged to carry out specific functions regarding spills of oil and hazardous materials. These functions include contingency planning, response activities, and prevention and control. The Division of Oil and Hazardous Materials, Office of Water Programs of EPA, is responsible for carrying out such functions. In early 1970 the Division planned, developed, organized and implemented a program which facilitated a rapid response to spills of oil and hazardous materials throughout the United States. Experienced and well trained oil and hazardous materials program staff located among the ten EPA regional offices execute spill program requirements.

This report represents a formal documentation of selected field study activities for one major spill incident which initially occurred offshore Louisiana on December 1, 1970 and lasted until April 16, 1971. The report is based on data and information obtained through three field surveys undertaken by EPA. The field studies and activities were coordinated through the State of Louisiana's Wild Life and Fisheries Commission and Stream Control Commission.

The purpose of these field studies was to determine the areal extent of the spilled material, the fate of the spill, and the effect of the material on the biota. They were:

- The Caminada Bay - Barataria Bay physical, chemical and biological sampling conducted by EPA Region VI personnel assisted by the State of Louisiana.
- The offshore physical, chemical and biological sampling conducted by EPA regional personnel.
- Oceanographic and remote sensory survey by Texas Instruments, Inc.
- The joint physical, chemical and biological sampling conducted by EPA and contractor (Resources Technology Corp.).

In order to supplement EPA resources in biological, chemical and physical disciplines, several contractors located throughout the United States were selected through a competitive elimination process,

to assist EPA regional staff on spills of oil and hazardous materials. Resources Technology Corporation is one of those contractors selected to provide technical assistance to EPA during spill emergencies in the Gulf of Mexico area.

This report prepared by the contractor describes the efforts of the United States Environmental Protection Agency to document the post spill conditions in the vicinity of the spill incident. There are a total of four volumes to the complete report. Volume I is a brief Executive Summary; Volume II is a summary report of the entire effort; Volume III is data compilation of all sources, and Volume IV is detailed data compiled for use in the comparative background analysis. Because of the large amount of data, it was decided to print Volume II only. Copies of Volumes I, III, and IV are available for review in the Surveillance and Analysis Division, EPA Region VI, 1600 Patterson Street, Dallas, Texas.

H. D. Van Cleave
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Washington, D. C. 20460

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Dr. William George Blanton, Texas Wesleyan College, and Mr. Michael C. Robinson, Tarrant County Junior College; both affiliated with the RESOURCES TECHNOLOGY CORPORATION Fort Worth Operations, were instrumental to the success of this study and prime contributors to the data contained in this report.

Invaluable direction, guidance and assistance was afforded by staff members of the many federal, state and local agencies and industrial concerns, who, because of their numbers, cannot all be acknowledged here. However, among those to whom RESOURCES TECHNOLOGY CORPORATION is especially indebted are Messrs. Russell H. Wyer and H. D. Van Cleave, of the Division of Oil and Hazardous Materials, and J. Thornhill and R. Forrest of the Environmental Protection Agency's Region VI Office, whose administrative direction and technical guidance contributed greatly to the success of this program. Mr. E. H. Douglas of the Environmental Protection Agency in Baton Rouge, Louisiana provided much valuable technical assistance and aided inmeasurably in effecting coordination and information exchanges with contributing agencies. The earlier study efforts and information provided by the Environmental Protection Agency, Ada, Oklahoma, served as valuable basis for study data and planning of the program. Analyses of many of the biological and chemical samples were accomplished and reported, and assistance provided in analytical techniques, by the Environmental Protection Agency Laboratories of Edison, New Jersey, Cincinnati, Ohio; and Baton Rouge, Louisiana. The efficiency with which efforts were coordinated, the expediency of support provided, and the cooperative spirit of individuals of these geographically dispersed organizations was a tribute to the Laboratories and the Environmental Protection Agency.

Finally, grateful acknowledgment is made of the many contributions of the other participating staff members of RESOURCES TECHNOLOGY CORPORATION who worked many long, hard and dedicated hours to the preparation and publication of this report.

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1.0 Introduction

On December 1, 1970, a blow out occurred on Shell Oil Company's Platform B in Block 26, approximately seven miles offshore of South Timbalier Bay. Eleven of the twenty-two producing wells were involved in the incident. While control, containment and clean-up efforts were underway, a series of field surveys were undertaken by the Environmental Protection Agency to determine the areal extent of the movement of the spilled material, the fate of the crude spilled, and the effect of the material on the environment.

The first of these was a study of the physical, chemical and biological conditions in the Caminada-Barataria Bay areas and in the Gulf in the area of the burning platform. Field sampling and study was conducted from December 13 to 18, 1970, and analytical work continued through November, 1971.

A second field study was conducted by Texas Instruments, and involved collection, correlation and analysis of oceanographic and remotely sensed data in the area of Platform B. The field survey was conducted from January 10 to 17, 1971; and the results were presented in the Texas Instruments final report entitled "Oceanographic and Remote Sensing Survey in the Vicinity of the Shell Spill, Gulf of Mexico, January 1971." This report was published bearing the date March 25, 1971.

The third study was the joint effort of the Environmental Protection Agency field team in Caminada and Barataria Bays and RESOURCES TECHNOLOGY CORPORATION, offshore with field sampling and study conducted from June 1 to 10, 1971. RESOURCES TECHNOLOGY CORPORATION participation was under Basic Ordering Agreement Number 68-01-0051.

This document reports the results of the study by RESOURCES TECHNOLOGY CORPORATION; and in addition, incorporates the results of the first and second studies. Surveys have been conducted to compile and evaluate background information from a multiplicity of sources to yield meaningful bases for comparison of the information gained during the studies from December 1970 through June 1971. These comparisons form the bases for many of the conclusions reached in this report.

The report is so structured as to facilitate review and assimulation of the data contained.

Section 2.0 defines the geologic, climatic and oceanographic parameters of the study area and the impact of these factors on life forms under study in the environment. In Section 3.0, a Biological and Zoogeophysical description of the study area is presented. Data and analyses presented in this section were based on data from all three studies. These detailed input data are presented in Appendices I and II

as data sheets, field logs, trip reports, study plans, sampling and analytical procedures; and background faunal data compiled for the periods 1950 to 1960.

In Section 4.0 of this report, the results of the studies are presented. Again, the reader need refer to the Appendices I and II for detailed discussions of data sources and techniques employed.

The significant conclusions drawn from this study are presented in Section 5.0. Section 6.0 contains a Bibliography of these publications from which much valuable information and data were drawn in the conduct of this study.

2.0 Geological and Historical Review of the Study Area

Description of the Area (General)

The study area lies in the coastal region between Vermillion Bay on the west and the southwestern margin of the Mississippi Delta. The area is characterized by marshes (660 square miles associated with the Atchafalaya River below Morgan City and about 470 square miles below the levees associated with the Mississippi River). Also associated with these systems are vast areas of estuarine and marine waters. The coastline is characterized by numerous bay systems, communicating through natural and artificial passes, and with fresh water distributaries of the Atchafalaya River. The lower Atchafalaya Basin exhibits an intricate system of lakes and channels. The Mississippi River, being leveed almost to its mouth, permits little drainage to the west below Baton Rouge to the Atchafalaya Basin.

2.1 Geological and Historical

The lower Mississippi River Basin consists mainly of alluvium deposited during the final cycle of the most recent glaciation. During the last glacial stage when the sea level was much lower, the lower valley became deeply eroded and entrenched between the valley's walls. The rise in sea level which accompanied the melting of glacial ice caused the valley to fill with gravels and coarse sand in the lowest strata. The subsequently deposited alluvial plain consists primarily of sand and silt, grading to fine sand and silt in the lower portion of the basin with extensive deposits of clay scattered through the sand and silt deposits.

Since distributaries are usually a shorter distance from the Gulf and the gradient is steeper, the percentage of flow in the main channel decreased until the old channel became abandoned. Previous routes of the Mississippi River have covered most of southern Louisiana. The Atchafalaya River is presently the only major distributary of the Mississippi River. The Atchafalaya River was formed during very recent geologic times and was a minor stream until about 1900. Developments for navigation and flood control have aided a natural tendency for the river to enlarge.

An extensive delta has formed at the extreme lower portion of the Mississippi River. The formation of natural levees of heavy sediments near the stream bank resulted in drainage away from the stream to low ground near the basin walls. These natural levees on both sides of the river resulted in the extension of a delta into the Gulf of Mexico. The delta is geologically recent in origin. Figure 2.1 illustrates the geo-oceanographic regional classification into which

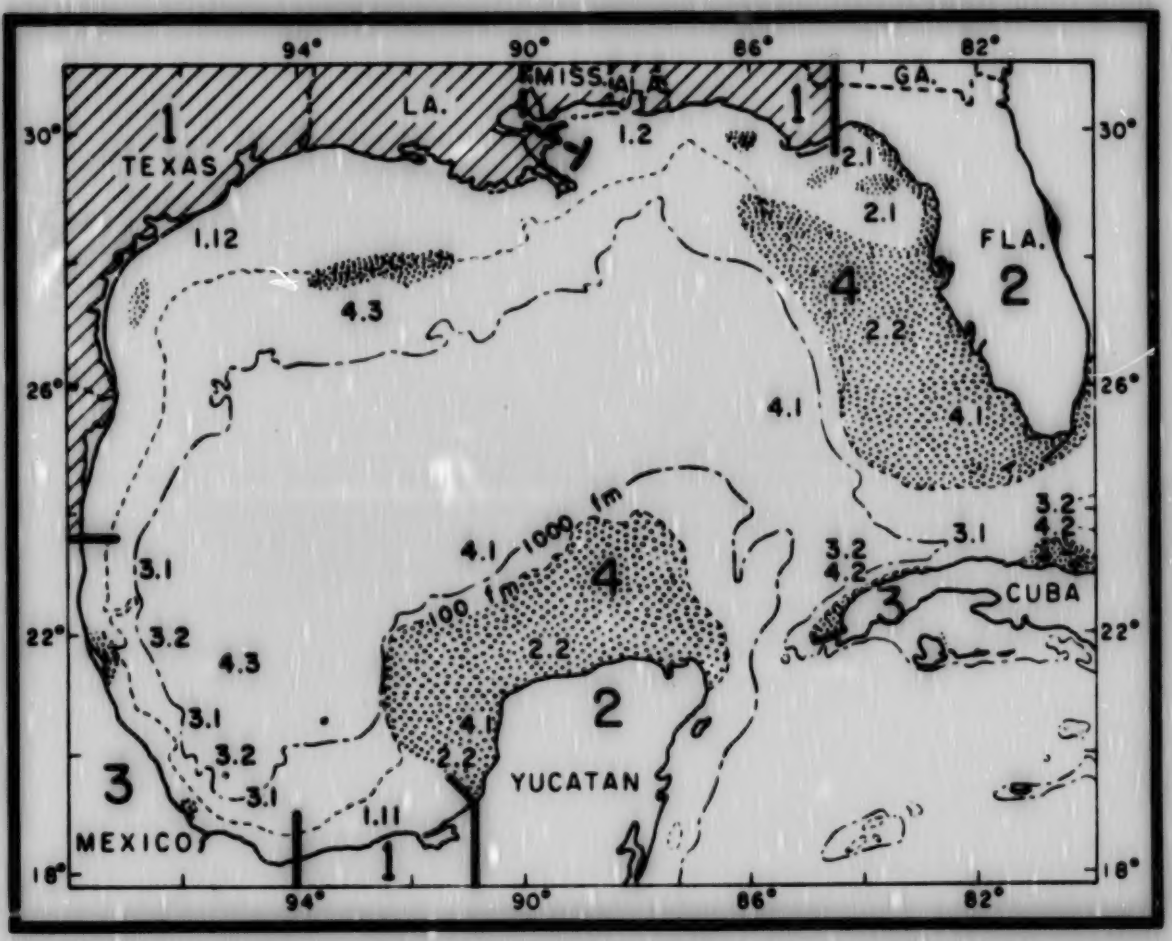

Figure 2.1 Regional geo-oceanographic classification, shorelines and coasts, Gulf of Mexico: 1, alluvial coasts; 2, drowned limestone plateaus; 3, young orogenic coasts; 4, biogenous (organic) development on various coasts. Sub-sectors: 1.1, deltaic coasts with 1.11, unentrenched simple deltaic plain, and 1.12, entrenched and embayed compound deltaic plain. 1.2, terraced deltaic coastal plain; 2.1, unsimplified to little simplified drowned karst; 2.2, limestone karst with beaches; 3.1, erosional, and 3.2, depositional, orogenic coasts; 4.1, broad shelf; 4.2 shelf absent to narrow; 4.3 lesser biogenous development (more extensive than shown). The two southerly Mexican 3.1 Sectors are volcanic salients.

(Gulf of Mexico, its origin, waters, and marine life; U. S. Dept. of Interior; Fish and Wildlife Service Fishery Bulletin 89).

the study is fitted and Figure 2.2 shows the sedimentary provinces of the Gulf of Mexico (Riley, 1937-38).

2.2 Nature of the Coastline

An attempt has been made to characterize the shoreline of the north central Gulf of Mexico. In this characterization, a more detailed discussion of the study area will be fitted. Shoreline type, bottoms, relief, and dynamic mechanisms presently active in shaping this coastline are considered.

2.2.1 Gulf of Mexico

The Gulf of Mexico has a surface area of approximately 600,000 square miles and is connected with the Caribbean by the Yucatan Passage (100 miles wide and about 1,000 fathoms deep) and with the Atlantic Ocean by the Florida Straits (less than 100 miles wide and less than 300 fathoms deep). The distance across the Gulf varies from 500 to 1,000 miles, depending on the route. The shoreline from Cape Sable to Yucatan is roughly 5,000 miles long, not considering bays and islands. That part of the Gulf Coast under consideration (western vicinity of the Mississippi Delta) possesses the following geomorphological features: a coastal plain, marshes, bays, river deltas, alluvia and a highly irregular coastline. Figure 2.3 shows the locations of the important landmarks of the system under study.

2.2.2 Coastal Plain and Continental Shelf

The characteristic inland feature of the study area is the gently sloping coastal plain. This plain is continuous in the east with the South Atlantic coastal plain and extends southward to Mexico just south of Brownsville, Texas. The plain slopes at a rate of five feet per mile into tidal marshes just inland from secondary bays and is characterized by numerous lakes and channels. As the coastal plain reaches the Gulf shoreline the slope increases from 8 to 12 feet per mile, except in the immediate vicinity of the delta.

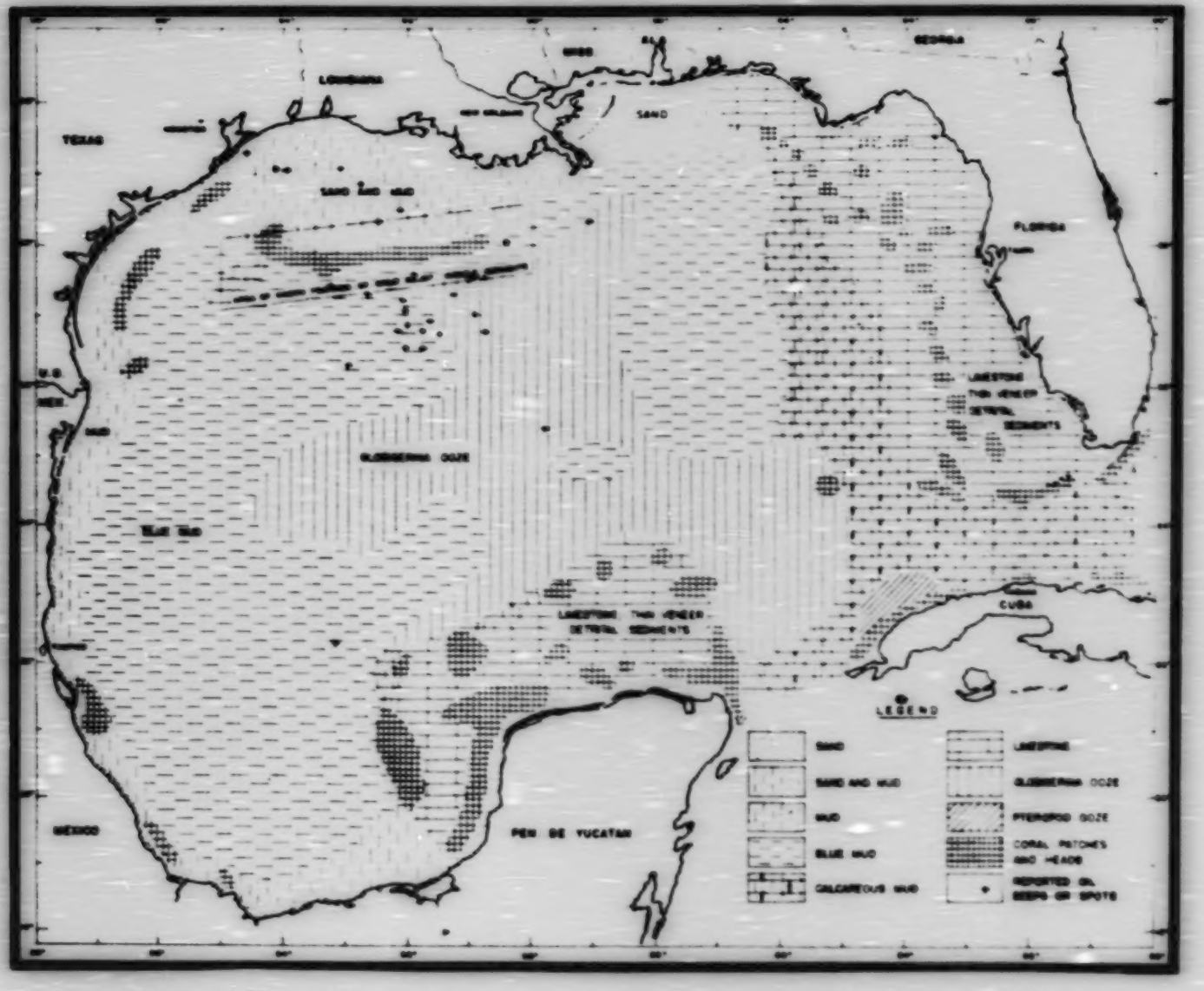

Figure 2.2 Sedimentary provinces of the Gulf of Mexico. Data compiled from many sources (U.S.D.I.; F.W.S. 1954).

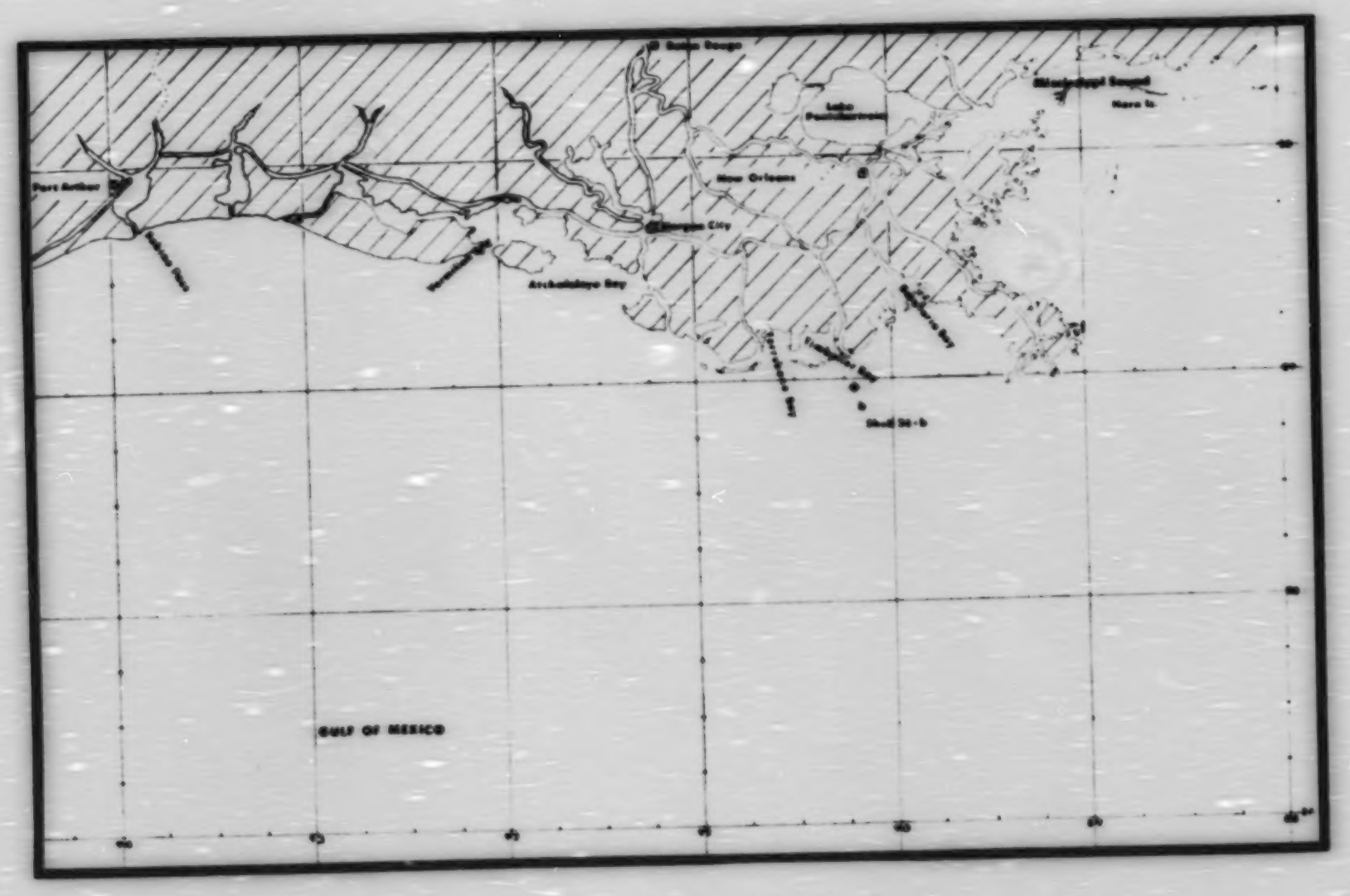

Figure 2.3 Location of landmarks

2.2.3 Marine Marshes

Marine marshes lie on the shoreward periphery of the shallow bays and are formed by precipitated sediments from land runoff and by dead lignacious materials. These marshes are characteristically covered with vegetation and represent highly productive zones of the ecosystem. The alternate exposure and inundation of these marshes by wind and lunar tides contribute to the overall productivity of associated bays. Some of the mechanisms which may be active in the enrichment and productivity of these marsh areas are discussed by Oppenheimer and Ward (1963).

2.2.4 Dynamic Processes

Some disagreement exists between various authorities concerning classification of coastlines or even the need for a classification system (Johnson, 1919; Russell, 1949; Hedgpeth, 1953). However, for the purpose of characterizing various coastlines for this study, some classification system is required. Because no uniform system has been accepted, the classification presented herein is arbitrarily chosen from those available as best suited to the needs of this study. On this basis and because of previous documentation of a particular system to the Department of the Interior (Pequegnat, Blanton, Bottom, and Bright, 1967), the classification system of Gilluly, Waters, and Woodford (1959) was chosen.

According to this system the coastline of the study area is classified as "emergent" or depositional. Dynamic processes such as river discharge, delta formation and wave action have lead to an extension of the coastline into the Gulf of Mexico.

2.3 Climate

2.3.1 Average Conditions

The climatic zones bordering the Gulf of Mexico are shown in Figure 2.4. The study area lies within the temperate mesophytic (humid) zone. This zone is characterized by rainfall of from 40 to 80 inches per year, temperature from 5° to 32° C (41 to 89°F) and bay salinities from 0% to 32%. The predominant

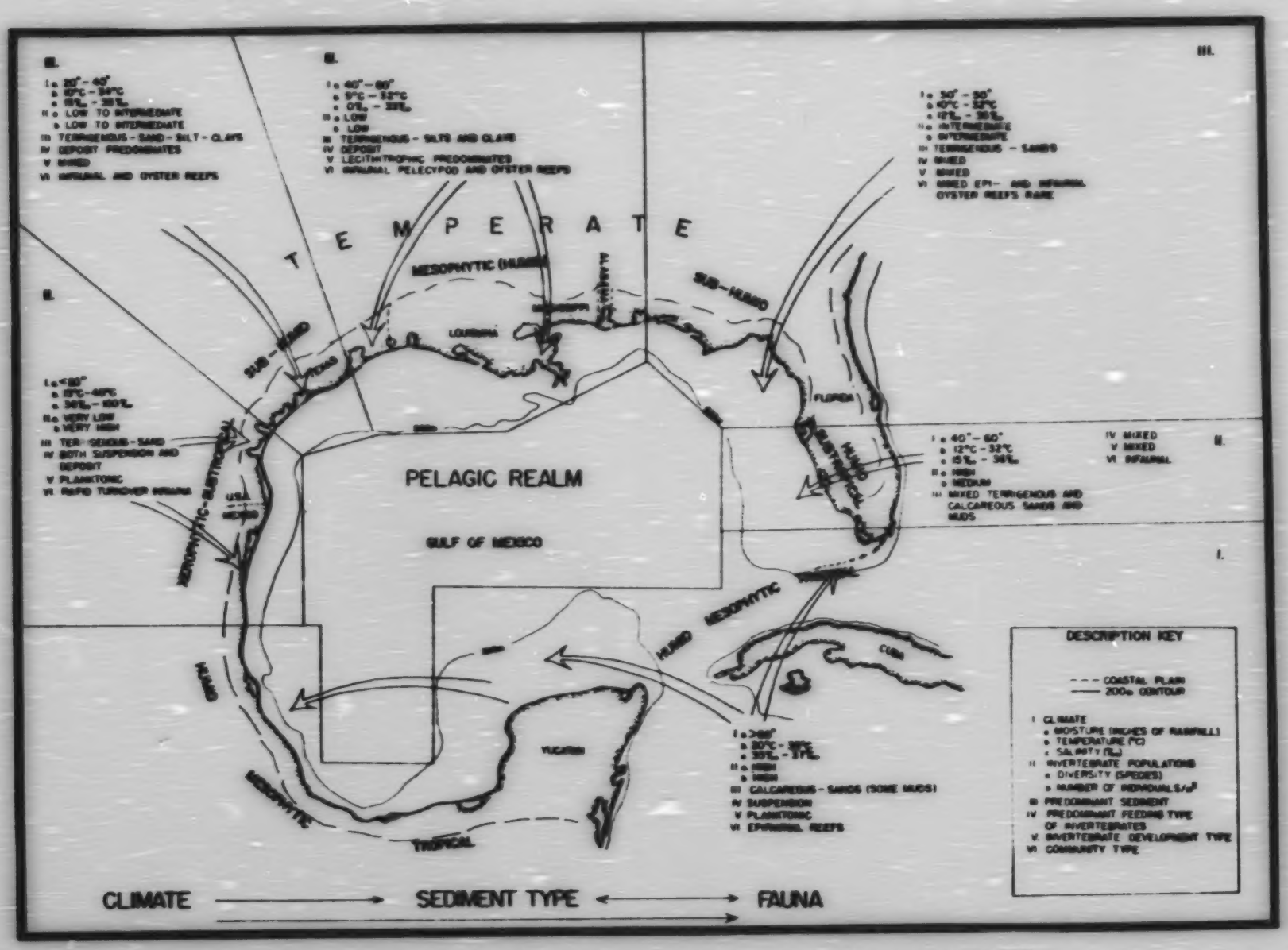

Figure 2.4 Schematic of climatic zones and ecosystem components for the coastal zone of the Gulf of Mexico (Parker and Blanton, 1970).

sediment in bays of this area is terrigenous (silt and clay). The predominant feeding types found among benthos are deposit and suspension feeders, associated with infaunal pelecypod and oyster reef communities. The mean annual precipitation of the area ranges from 35 to 54 inches and the temperature ranges from mean lows of -7.2 to 6.7°C (19 to 44°F) in January to mean highs of from 29.4 to 32.8°C (85 to 91°F) in July (FWPCA, 1969).

2.3.2 Unusual Tides and Storm Surges

2.3.2.1 Lunar Tides

In the Gulf of Mexico, tidal action is damped and the range of the tide is reduced, averaging 2 to 3.5 feet. Tidal currents in narrow inlets affect the migration of organisms through passes. The tides in the Gulf are of two types; tropical and equatorial. Tropical tides are those of maximum range occurring as the moon reaches its maximum declination north and south. These are daily tides with one high and one low each 24 hour period. Equatorial tides are those of minimum range, occurring as the moon passes the equator. These are semi-daily tides with two highs and two lows each 24 hour period.

2.3.2.2 Storm Surges

Figures 2.5A and 2.5B depict the frequencies of occurrence of hurricane waves of specific significant heights and periods at the 100 fathom curve off Gilchrist which lies to the west of the study area on the northeastern Gulf of Mexico. The isolines give the frequency (1 in h years); the polar co-ordinates represent wave heights and the radial lines represent approach direction toward the shore station.

As waves progress toward the coastline their heights are reduced by shoaling, refraction, and friction. A particularly detrimental feature of hurricanes is the storm tides caused by barometric suction and wind stress on the sea surface. These result in a "piling up" of water near the coast. Storm tides in excess of 15 feet are not uncommon and have made tragic depredations upon the Gulf and east coast seaboards.

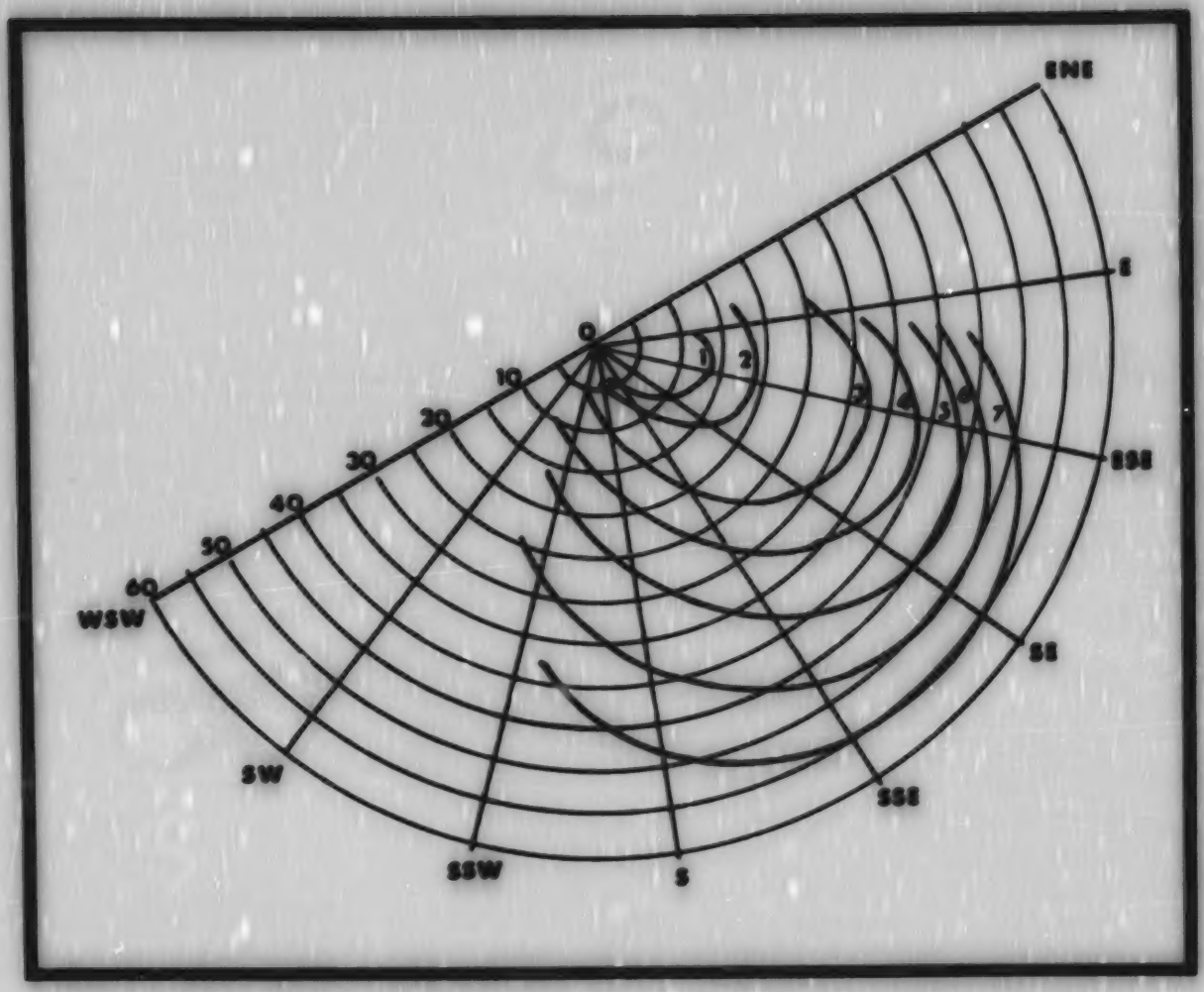

Figure 2.5A Hurricane wave height frequency (deep water offshore station) .... 100 fathom depth contour.

Plot 1 - 1 in 1½ years frequency
Plot 2 - 1 in 2 years frequency
Plot 3 - 1 in 5 years frequency
Plot 4 - 1 in 10 years frequency
Plot 5 - 1 in 20 years frequency
Plot 6 - 1 in 50 years frequency
Plot 7 - 1 in 100 years frequency

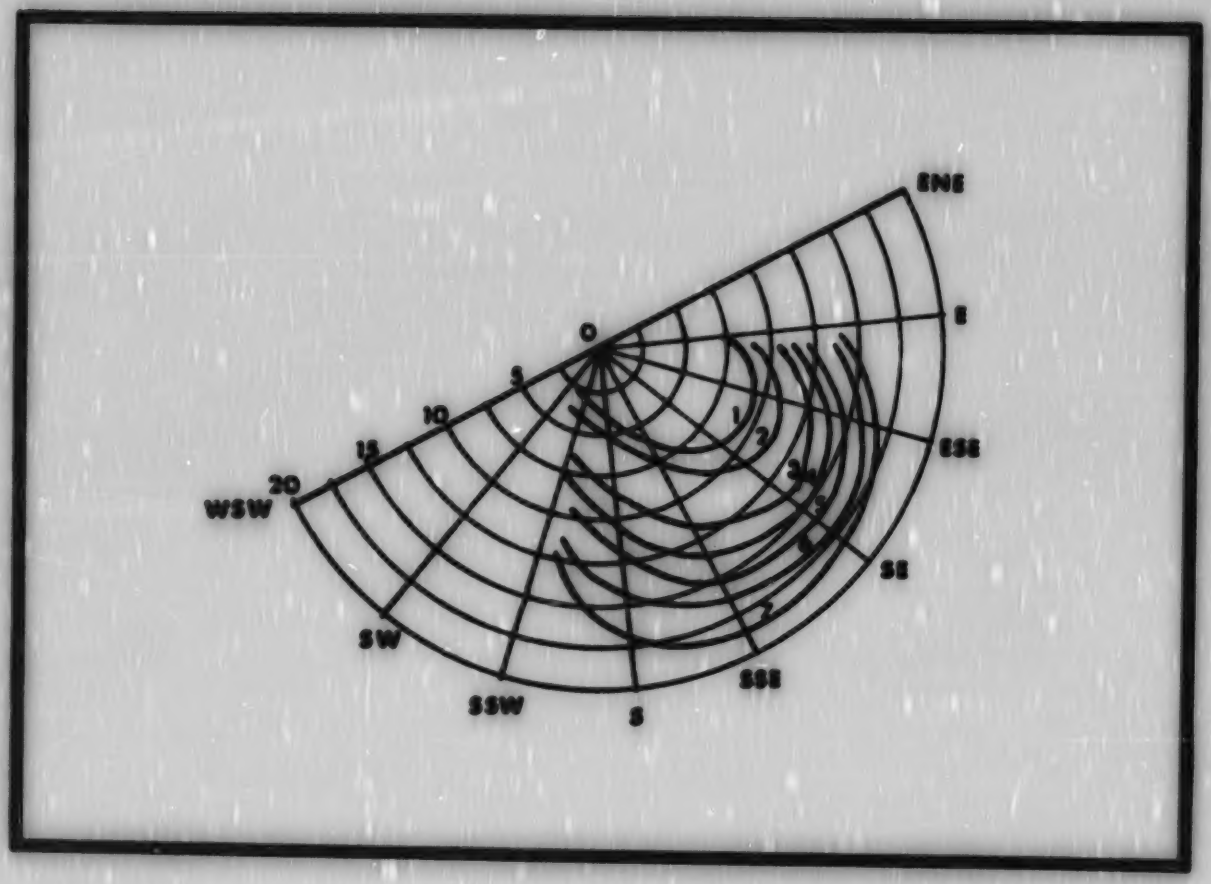

Figure 2.5B Hurricane wave period frequency (deep water offshore station) . . . . 100 fathom depth contour

Plot 1 - 1 in 1½ years frequency
Plot 2 - 1 in 2 years frequency
Plot 3 - 1 in 5 years frequency
Plot 4 - 1 in 10 years frequency
Plot 5 - 1 in 20 years frequency
Plot 6 - 1 in 50 years frequency
Plot 7 - 1 in 100 years frequency

2.3.3 Hydrology

2.3.3.1 Rainfall and River Discharge

The Mississippi water shed covers about 1,243,600 square miles. For the period of time between 1920 and 1949, a maximum discharge rate of 1,360,000 Cfs and a minimum discharge of 49,200 Cfs were observed. Rainfall in the vicinity of Barataria Bay ranged from a monthly average of 3.5 to a monthly average of 7.0, with a monthly mean of 5.18 inches. Since these data cover a time span of nearly 30 years they should serve well as baseline values for the study area. Relative seasonal fluctuations in monthly averages are typified in Figure 2.6 which shows monthly rainfall in Barataria Bay for 1949.

2.3.3.2 Water Temperature

The daily range of water temperatures in lower Barataria Bay is shown in Figure 2.7. These data were compiled for the 1948-1949 period from 100,000 measurements. The maximum range within one 24 hour period was about 8°C. The range of temperature over the full seasonal cycle was from 35°C in July to 7.5°C in February or a total range of 27.5°C. From these data we can deduce that water temperatures may vary significantly within the span of any one day or from season to season. The mean monthly water temperature maxima and minima for Barataria Bay during the period 1920-1947 are presented in Figure 2.8. The temperatures of coastal waters appear to be controlled by large scale thermal regimes from the Gulf of Mexico. "Typical" surface isotherms are shown in Figure 2.9, winter, and Figure 2.10, summer. Thermal gradients are generally increasing from the northern Gulf southward to Yucatan. These gradients become more pronounced during the winter spanning a range of about 18°C in the study area to about 25°C in the Yucatan Straits. The winter temperatures in the study give way to summer temperatures of about 28°C.

2.3.3.3 Bay Salinities

Bay salinities of the area are influenced by many of the same factors which operate on bay systems elsewhere

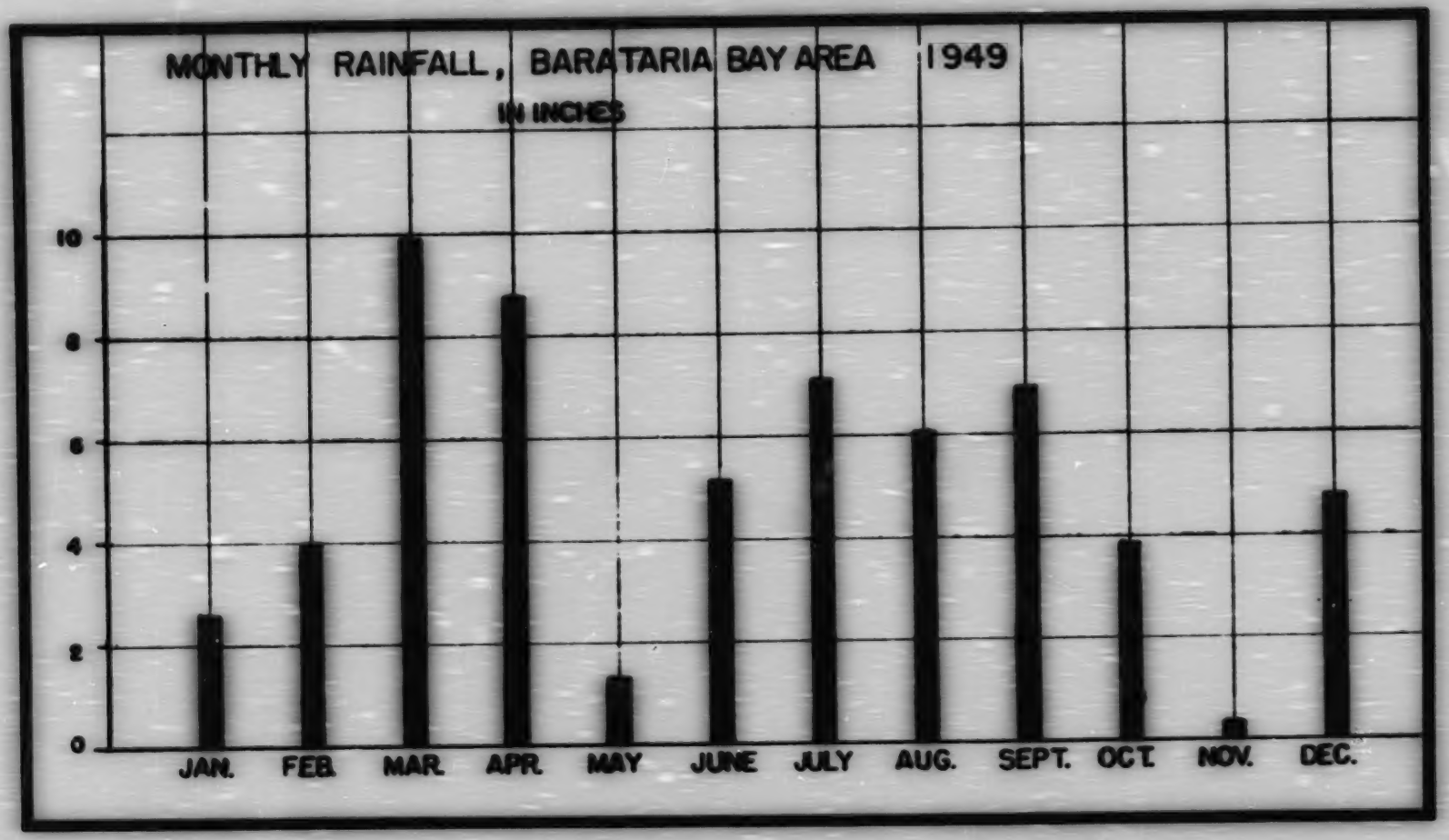

Figure 2.6 Monthly rainfall, Barataria Bay Area, 1949 (Mackin and Hopkins, 1961).

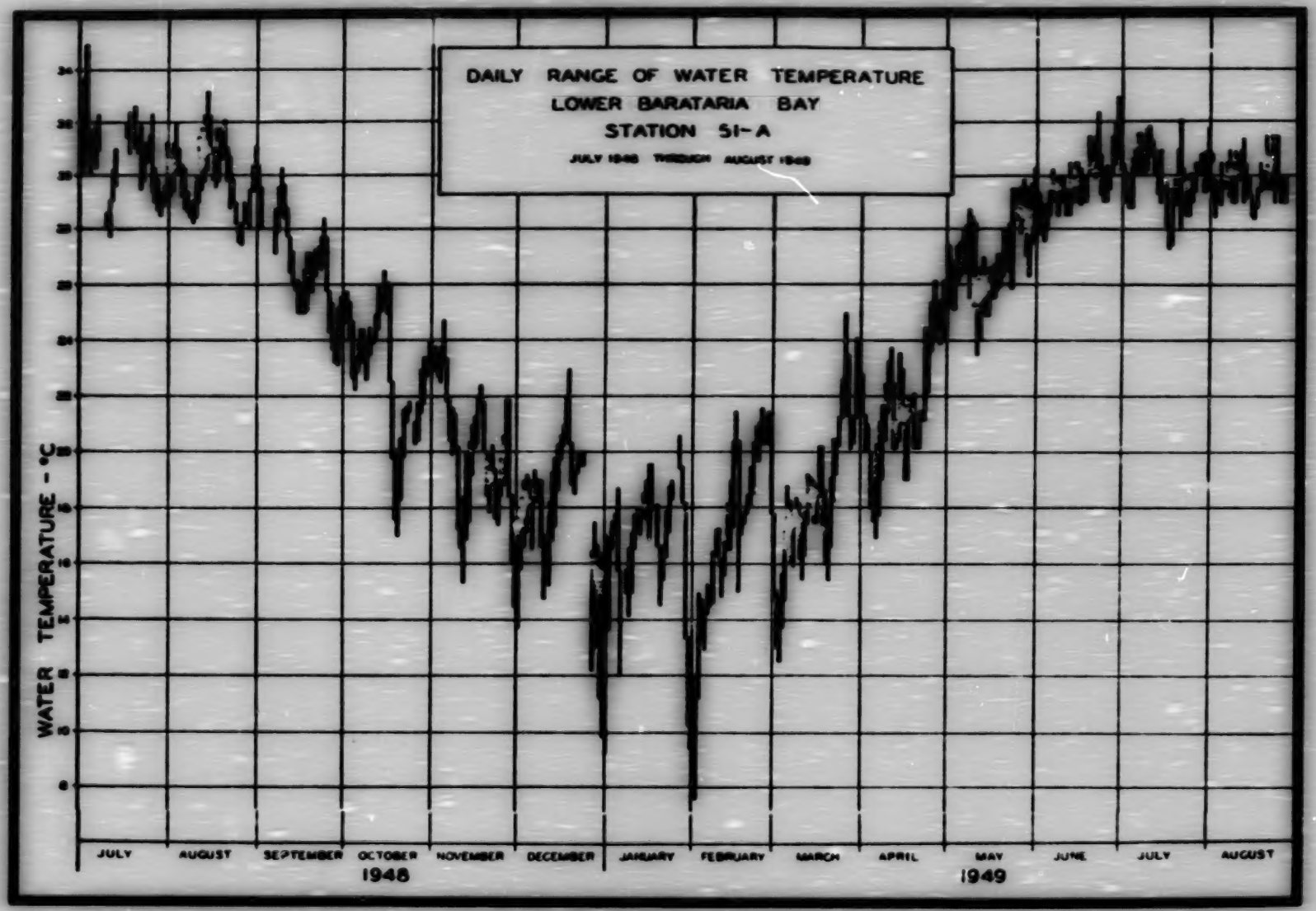

Figure 2.7 Daily range of water temperature - lower Barataria Bay July 1948 through August 1949 (Hewatt, 1953).

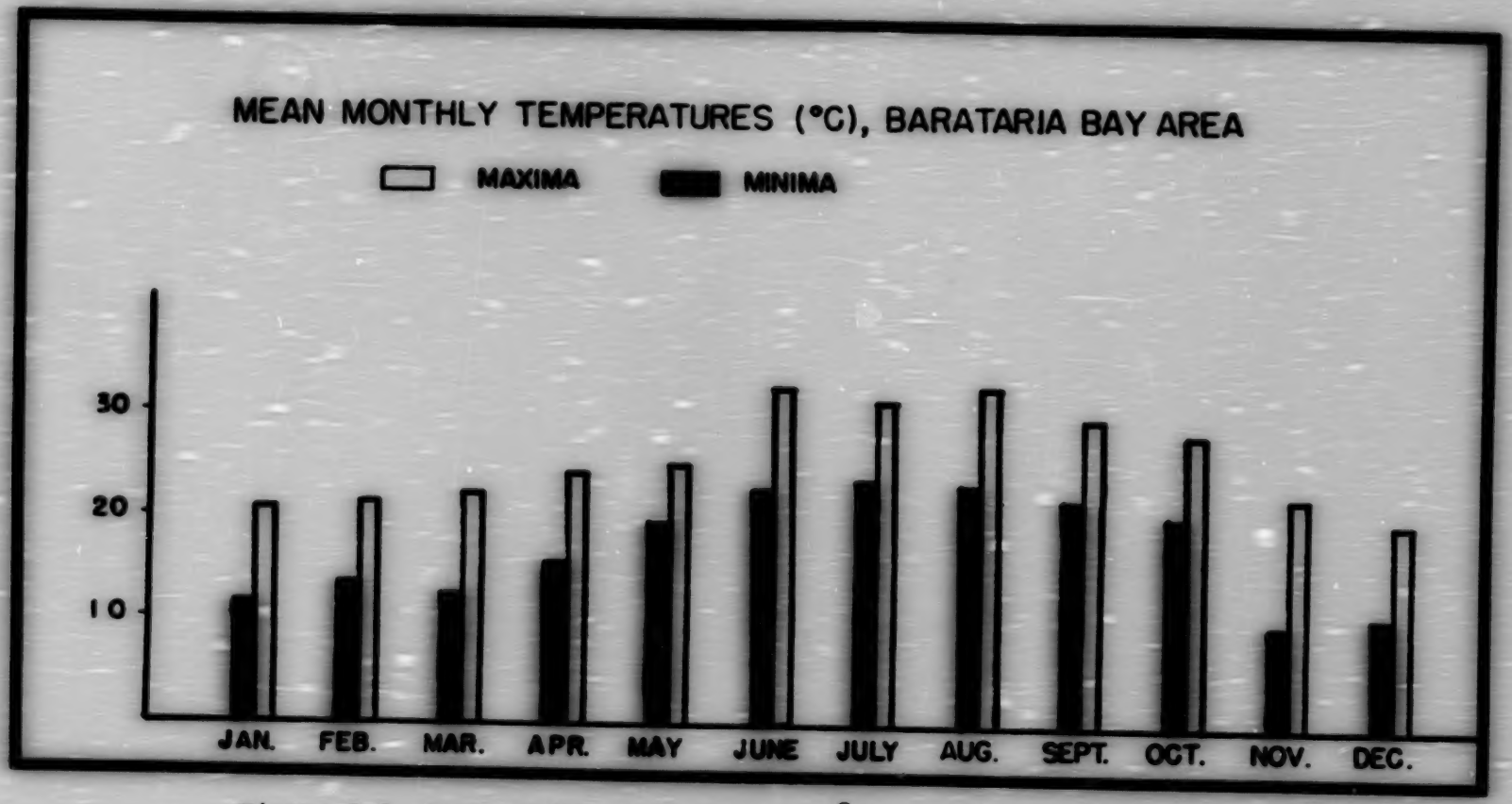

Figure 2.8 Mean monthly temperatures (^{o}C), Barataria Bay Area (Mackin and Hopkins, 1961).

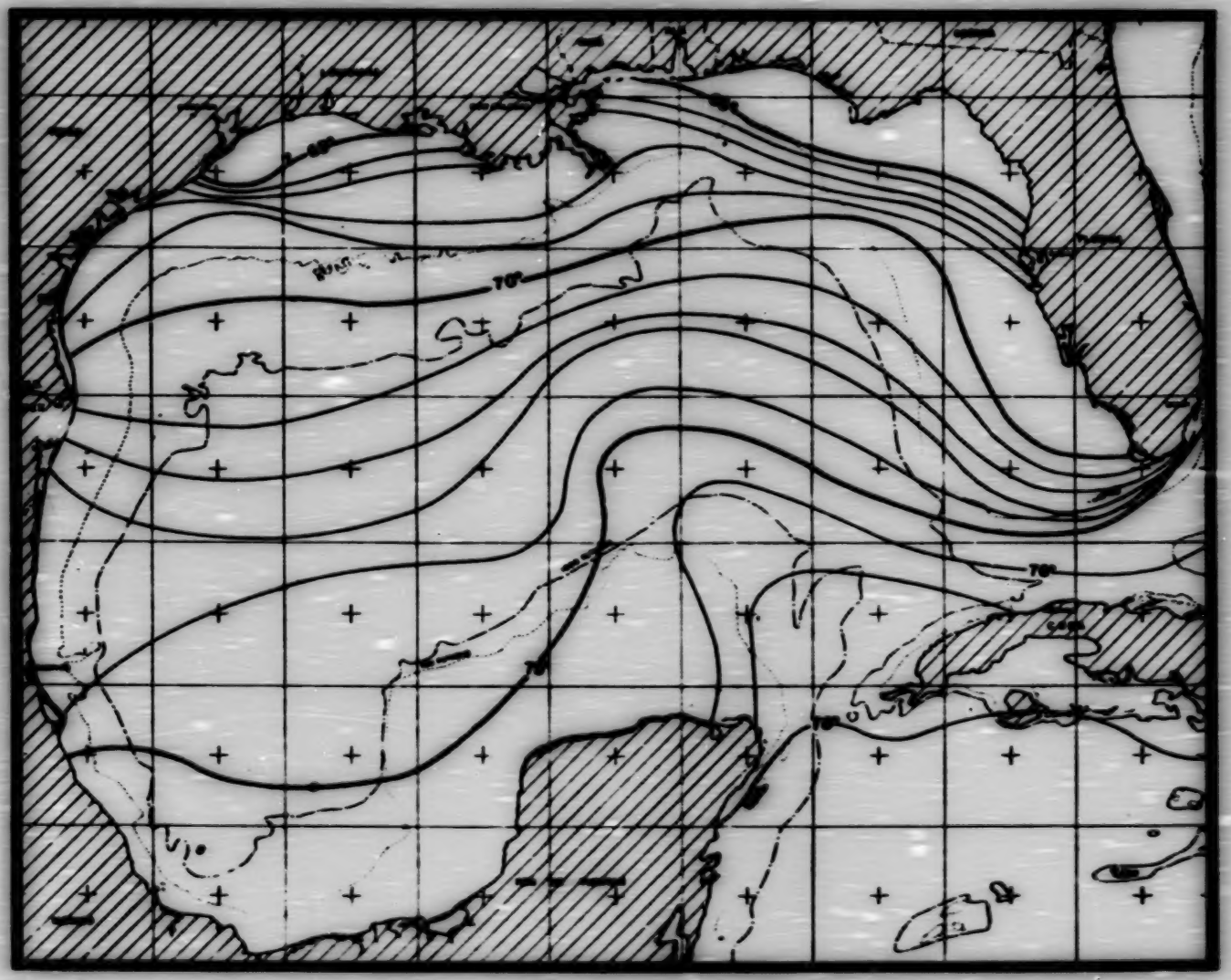

Figure 2.9 Average sea surface temperatures for February (after Fuglister, 1947).

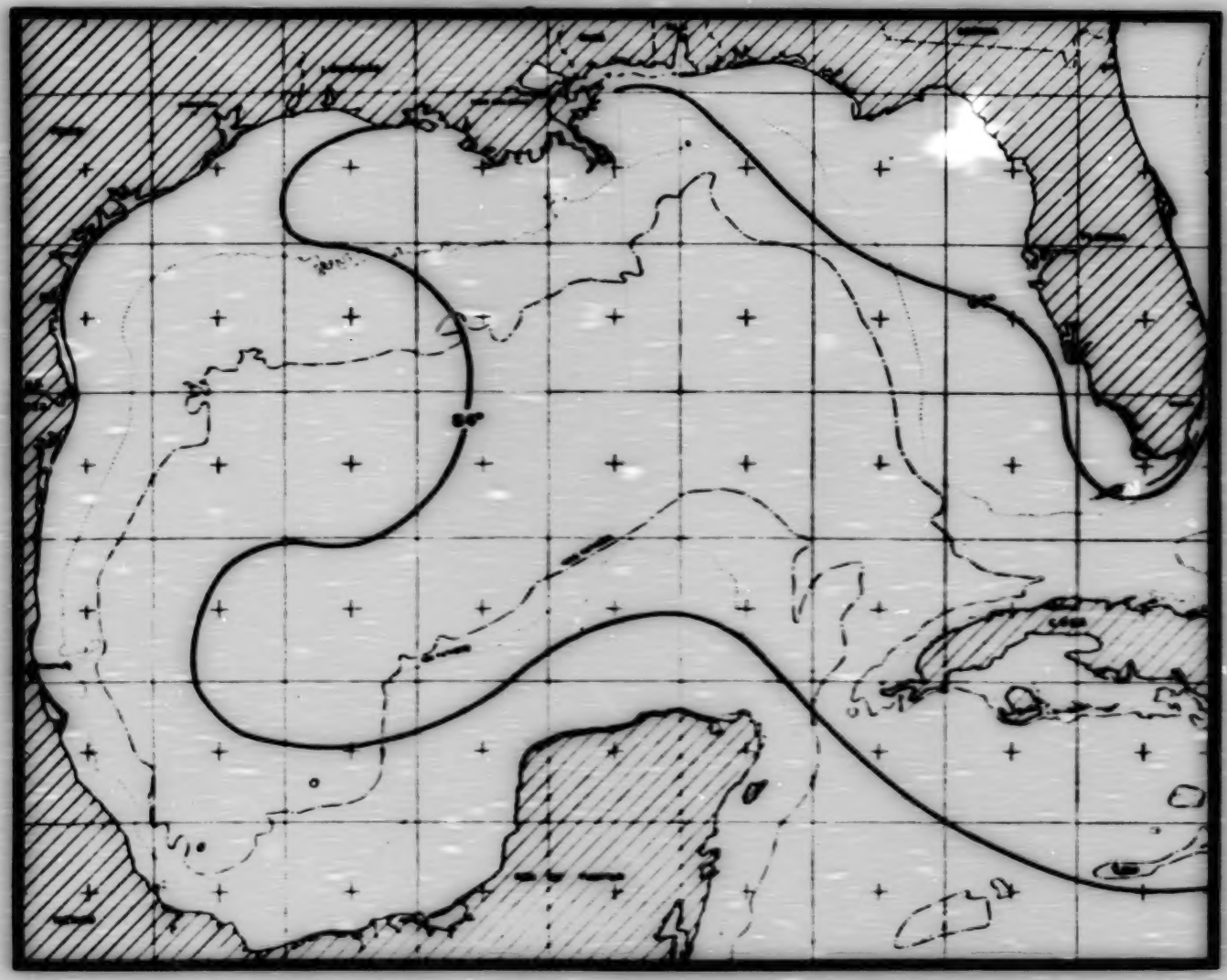

Figure 2.10 Average sea surface temperatures for August (after Fuglister, 1947).

on the Gulf coast. Some of these factors are lunar tidal-currents, wind tides, wind driven currents, rainfall, sand-bar islands (barrier islands), evaporation, and to a high degree the discharge rates of the Mississippi River and its distributaries. Modifications of the lower Mississippi for flood control purposes have greatly altered the various bay ecosystems within the study area.

Historically speaking, the protozoan *(Dermocystidium)* has been considered the most damaging oyster predator. Conversations with members of the Louisiana Wildlife and Fisheries Commission, however, reveal that the principal oyster predator in Louisiana Bays is now the oyster drill *(Urosalpinx)* and occasionally the starfish *(Luidia clathrata)*. This change has resulted from blockage in the lower Mississippi distributaries and the resultant elevation of bay salinities. As fresh water sources are diminished, salt water from the Gulf has intruded further into the bays and oyster production extended further up into bayhead areas.

An associated problem accompanying the blocking of distributaries by flood control and navigation measures is the reduction of sediment recruitment from upstream sources. This has caused the area to shift toward a new deposition-erosion equilibrium. This shift has introduced excessive erosion to certain delta areas.

Although not as well studied, Timbalier and Terrebone Bays in the study area possess similar geomorphological and hydrological features to Barataria Bay. Most of the statements concerning Barataria Bay may be applied to Timbalier and Terrebone Bays as well.

Within the bays, salinities may vary from near 0 to 35 parts per thousand(°/oo) depending on rainfall and evaporation. The mean salinity for lower Barataria Bay is about 20°/oo. Coastal salinities may range from normal Gulf salinities near 34°/oo to lower salinities depending on location of Mississippi River discharge. During periods of upwelling, salinities in excess of 34°/oo may occur within a few miles offshore.

2.3.3.4 Oceanic Currents Associated with the Study Area

It must be noted that the characterization of inshore currents of the study area was hampered by scarcity of available information. This is apparently the general case for other sections of the United States coastline as well (Pequegnat, et al, 1967). The current studies performed by Texas Instruments under Contract 68-01-0017 for the Environmental Protection Agency reveal that near

shore currents may be influenced by local winds. At this point, any predictions of nearshore currents would be largely speculative in nature and unsuitable for baseline comparisons. The assumption can be made, however, that surface currents are of major importance, because of controlling depths (60').

Certain data are available concerning offshore and Gulf surface currents compiled from U. S. Navy Hydrographics Office pilot charts and published in Fisheries Bulletin 89, 1954. These schematics are shown in Figures 2.11, 2.12, and 2.13.

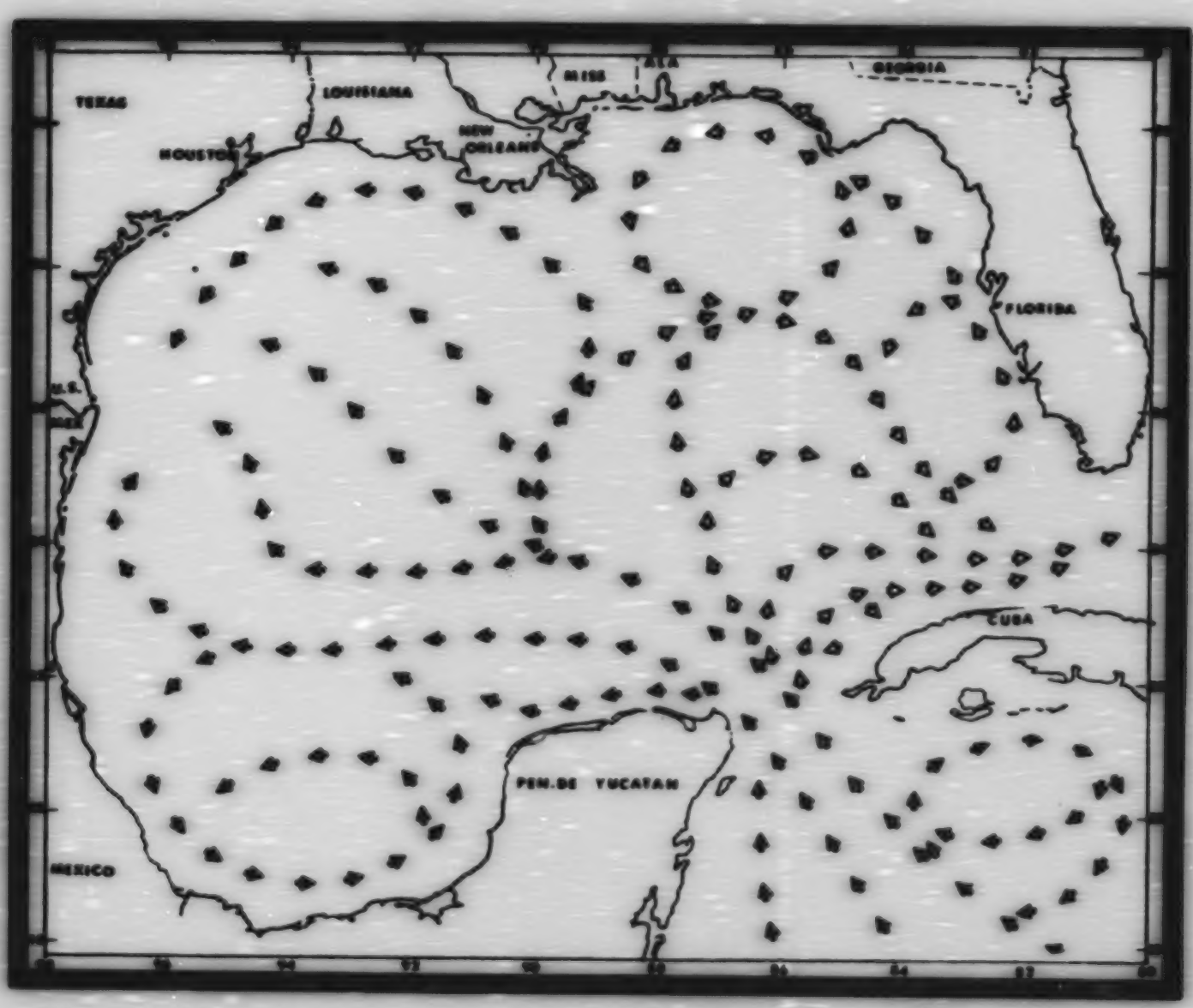

Figure 2.11 Surface ocean currents in the Gulf of Mexico in December

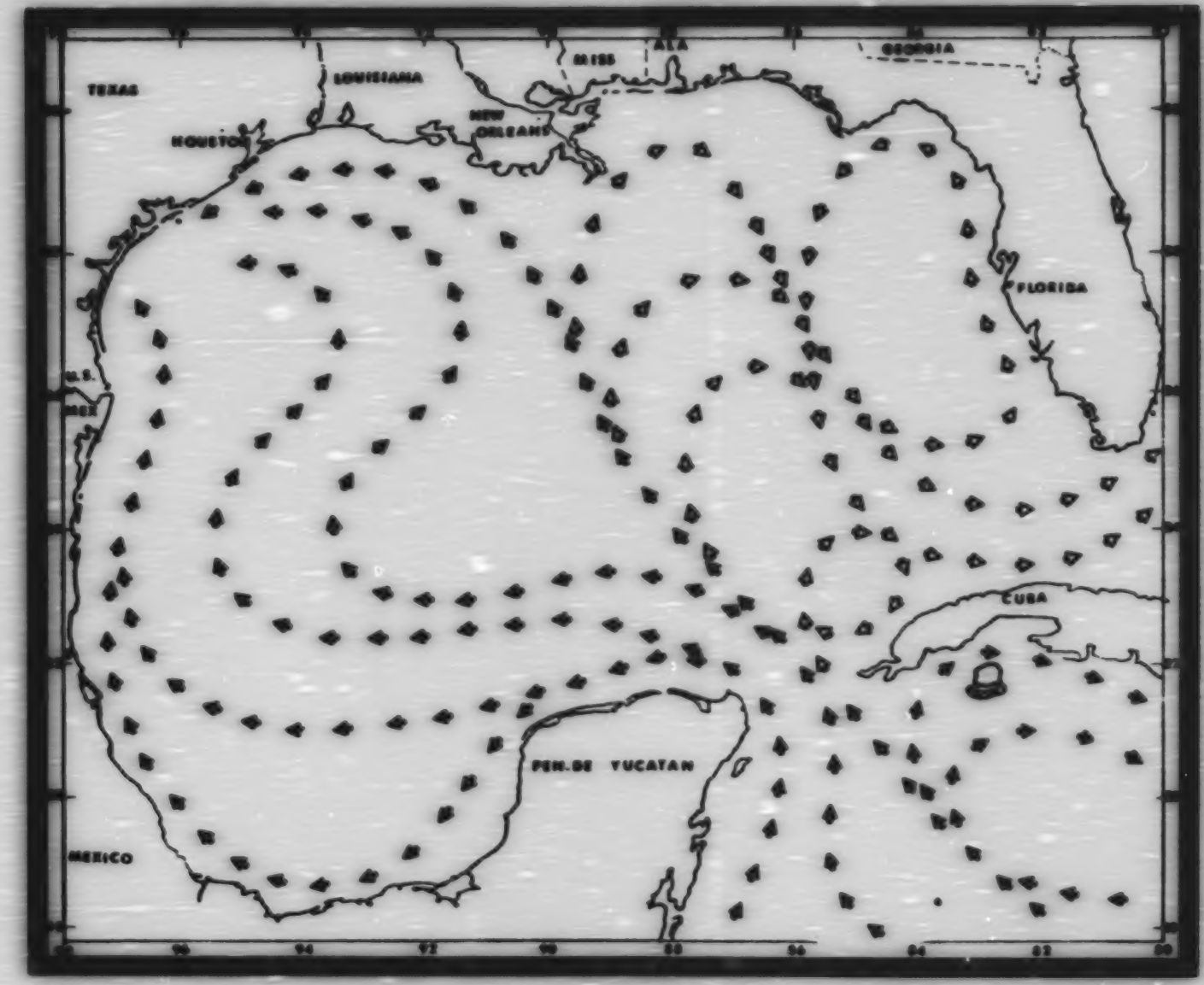

Figure 2.12 Surface ocean currents in the Gulf of Mexico in June

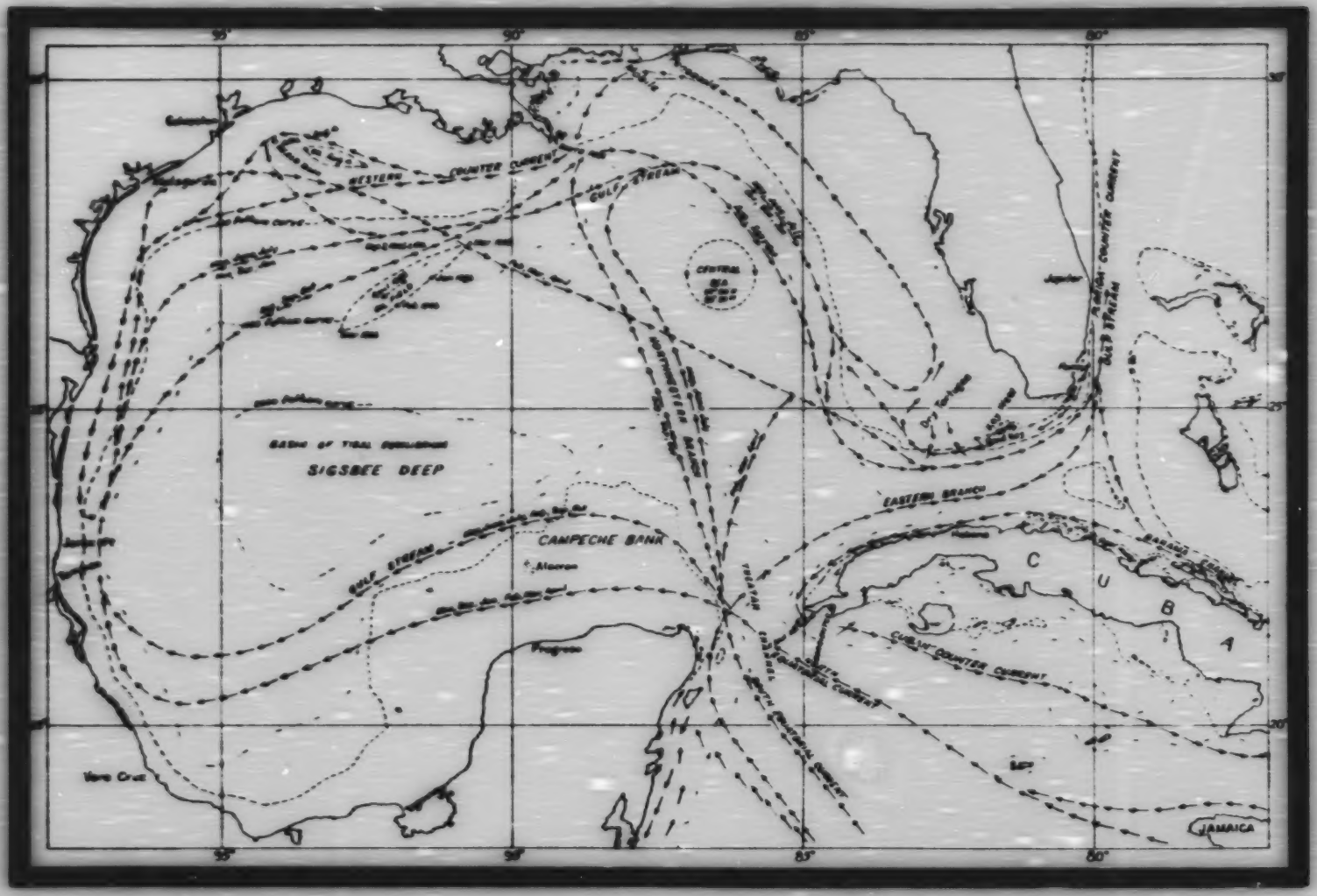

Figure 2.13 Gulf Stream in the Gulf of Mexico shown by Soley's chart, 1914. The currents as they exist during the different seasons.

3.0 Biological and Zoogeographic Review of the Study Area

3.1 Description of the Northern Gulf and Ecological Factors Affecting the Fauna

The northern Gulf of Mexico may be characterized as an area of temperate and subtropical climates, with a mean surface water temperature range of 18° - 30°C and meteorological areas ranging from xerophytic (arid) to mesophytic (humid). Ecological factors throughout the northern Gulf are quite varied. The eastern portion of the Gulf and the southwestern coast of Mexico are uniformly subtropical, while the northcentral and northwestern coastlines range from subtropical in the summer to temperate in the winter. As would be expected in a region of such variation, the faunal assemblages of the northern Gulf are subjected to severe ecological stresses and populations are maintained largely through recruitment. Strictly endemic forms constitute less than 10% of the native populations (Hedgpeth, 1953), while the distribution of the populations is dependent upon prevailing current patterns within the Gulf. A brief discussion of the ecological significance of the climatological factors and current patterns follows.

The ecological characteristics of each segment of the Gulf coast vary greatly, both from each other and in absolute values within segment. As previously shown in Section 2.0 the temperature, salinity, precipitation, and sedimentary types are noticeably disjunct between the northcentral and northeastern Gulf coast. For instance, the temperature ranges in the eastern portion of the Gulf coast vary from 12 - 32°C (55-90°F), while the remainder of the northern Gulf coastline temperature range from 5 - 38°C (40-100°F). Temperatures of the inshore and nearshore waters change from warm, subtropical in the eastern portion of the Gulf to cooler, more temperate in the central and northwestern regions. The surface water off Texas and Louisiana west of the Mississippi delta frequently reach temperatures less than 5 C°(40°F) in winter. This distinct temperature gradation between the eastern and northcentral regions of the Gulf implies that the two regions lie in different zoogeographic realms or provinces. This supposition is supported by the fact that a definite break in the distribution patterns of several temperate species occurs in Florida (Ekman, 1953). Such commercially valuable organisms as the oyster, *Crassostrea virginica*, and shrimp, *Penaeus* sp. display behavioral as well as distribution anomalies throughout the eastern Gulf. These resultant zoogeographic provinces have been characterized as temperate-subtropical (Texas and Louisiana west of the Mississippi delta) and subtropical (Florida and the northeastern Gulf coastline).

The diversity of climatic and other ecological factors in the Gulf have resulted in a wide diversity of faunal assemblages. The high productivity of the Gulf coastline as shown in Figure 3.1 is evidenced by the abundance of oyster reefs, shrimp ground, sponge beds and serpuloid reefs. Inshore and nearshore faunal communities are often subjected to the stress of variable ecological conditions. A brief discussion of the population recruitment mechanism is therefore in order. Circulation patterns in the waters of the Gulf appear to be of primary importance in governing the dispersal of marine organisms and their larvae. The principal current patterns have been charted by Leipper (1954), Hedgpeth (1953) and Curray (1960). The chartings establish that the primary current inflow enters through the Yucatan Straits which is, in turn, derived from the western Caribbean currents with some influx from the Atlantic Gulf stream along the southern coast of Cuba. Upon entering the Gulf, the Yucatan current separates off the Mississippi delta into eastward and westward currents as shown in Figures 2.1 and 2.12 of Section 2.0. The eastward current feeds the eastern Gulf and eventually leaves through the Florida straits. The westward current splits into two major subdivisions, one along the central and northwestern coasts and one through the Gulf of Campeche. Both reunite in the vicinity of Padre Island. During the vernal and the autumnal equinox, the currents off Padre Island also show divergences eastward below the mouth of the Mississippi delta. During these fall and spring periods, when larval production is at its peak, large influxes of animals occur. Those animals entering during the spring will find environmental conditions very similar to those of their normal habitats. Those entering during the fall, however, encounter the vicious winters so characteristic of the Gulf coast. Animals entering this period, however, frequently establish themselves and eventueally spawn when conditions again become favorable. Since the currents upon which recruitment depends may flow eastward without a reverse pattern and since significant zoogeographical limits exist between the eastern and central portions of the Gulf, it might be expected that a stronger correlation would exist between the northwestern and northcentral areas of the Gulf coast than between either of them and the Florida coast. This may be seen in the disjunct distribution patterns between Florida and the remainder of the Gulf and in the fact that native faunal populations in Florida are frequently not shared in toto with the rest of the Gulf coast. Those populations which are shared are often less hardy in the Florida region.

3.2 Faunal diversity and Species Ranges

Much of the indigenous fauna of the northern Gulf of Mexico have been investigated only in restricted geographical areas. Specific catch records and data are particularly scarce when compared to the remainder of the continental coastlines

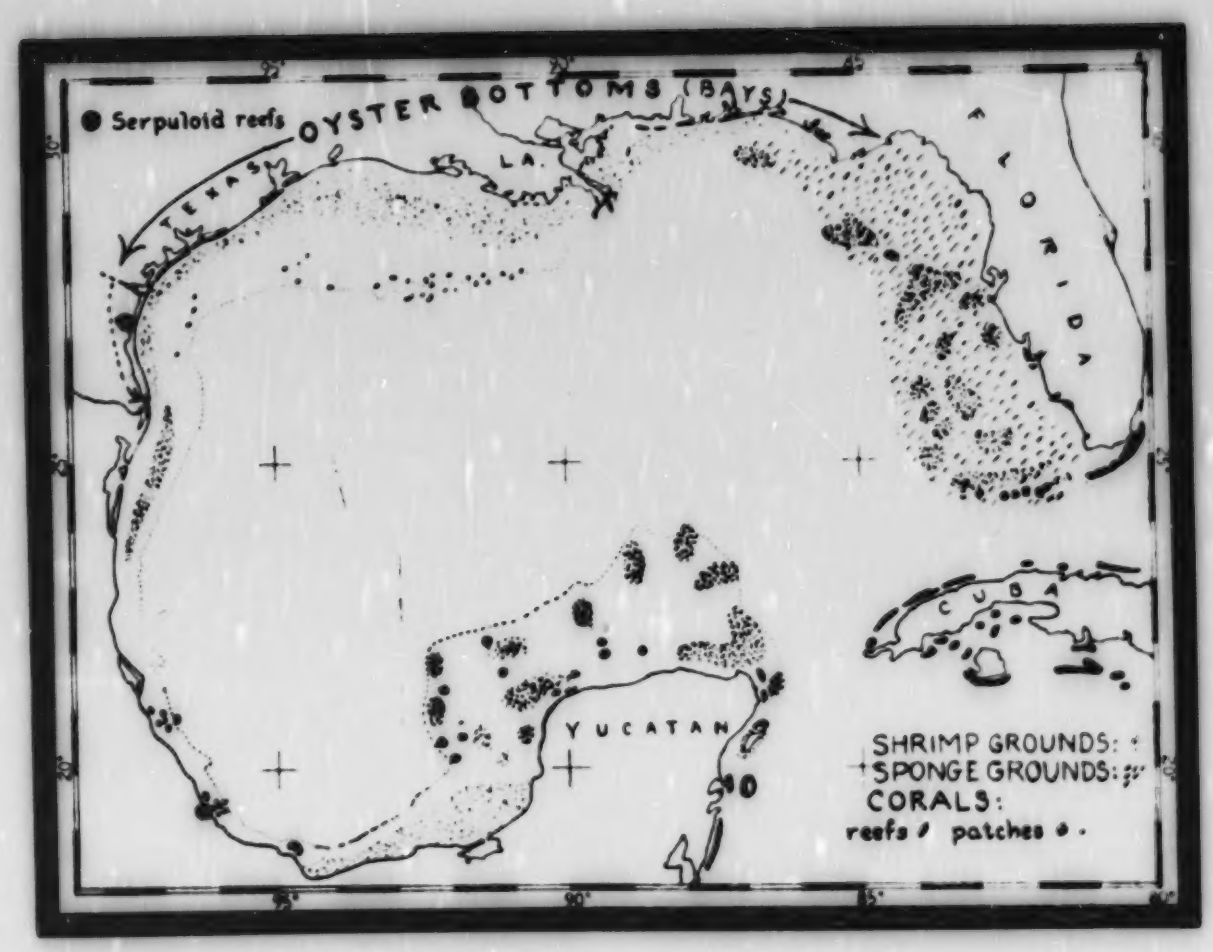

Figure 3.1 Abundance of oyster reefs, shrimp grounds, sponge beds and sepuloid reefs in the Gulf of Mexico.

of the United States. One comprehensive collecting program for the Gulf has been undertaken during recent years: the explorations by the National Marine Fisheries Service (then Bureau of Commercial Fisheries) U. S. Department of Commerce, during the years 1950-1960. Additional investigations are currently underway by the Hourglass cruises of the Florida Board of Conservation, but these data are not yet available. Therefore, in the compilation of background data for this report, the 1950-1960 data of the NMFS was used. In compiling this data, it was found that data on most of the smaller groups were incomplete. Accordingly, only those data pertaining to crustaceans, mollusks, and fishes have been included in the compilation as used for analytical purposes.

In this report, information has been assembled and data compiled into a checklist of species, comparative between the three principal provinces of the northern Gulf Coast-Texas, Louisiana west of the Mississippi delta, and Florida. In each instance, the relative abundance of a particular species within a given area has been recorded. However, the summary background data, for reasons previously noted, has been restricted to those data from the Central Gulf Coast area; the area of interest to this study.

Background data were compiled for the selected species in the following manner. First, the total number of sites where the species were taken was tabulated. From those sites, the sites located within the area of interest of this study were identified. Due to volume, these data, are not presented in this section but are included in Appendix II of this report, with specific site locations identified by latitude and longitude, and then positioned on a map which is also included.

From the data thus compiled a scale was developed which quantified the relative abundance of species in the locales of interest. These data are also presented in detail in Appendix II. As a final step in establishing "normal" populations in the study area, the data were refined to 1) identify, by species and relative quantitative populations, the species to be used for correlation with results of sampling conducted during this study and 2) to assign these species to their representative habitat in the inshore and nearshore environments. These data, representing the "normal" background data for purposes of analyses conducted in this study, are tabulated in Table 3-1. Figure 3.2 charts the habitatal areas classified with respect to the study area.

Table 3-1

Sequential Macro-Organismal Faunal Successions for the Central Gulf Coast

Sequential checklist of major invertebrate species distributional patterns illustrating faunal succession of microhabitats within the study area.

X = absent, not reported or doubtful in area
R = rare, seldom recorded
O = occur, usually encountered in small numbers
C = common, usually encountered in large numbers
A = abundant, always encountered throughout entire area.

Table 3-1

Sequential Macro-Organismal Faunal Successions
for the Central Gulf Coast

Freshwater/Brackish Water Assemblages (0 - 5 °/oo)	
Gastropoda	
Littorina irrorata	A
Neritina reclivata	A
Crustacea	
Uca pugilitor	C
Cambarus sp.	A
Low-salinity Assemblages (0 - 10 °/oo)	
Pelecypoda	
Rangia cuneta	C
Rangia flexuosa	O
Rangia carolinesis	O
Macoma mitchelli	C
Gastropoda	
Littoridina sphinctostoma	O-C
Crustacea	
Callinectes sapidus	C
Macrobrachium sp.	O
Intermittent Variable-salinity Assemblages (5 - 30 °/oo)	
Pelecypoda	
Rangia cuneata	O-C
Rangia flexuosa	O-C
Macoma mitchelli	R
Crassostrea virginica	A
Petricola pholadiformis	C
Gastropoda	
Littordina sp.	O
Amnicola sp.	O
Variable-salinity Oyster Reef Assemblages (10 - 30 °/oo)	
Pelecypoda	
Crassostrea virginica	A
Brachidontes recurvus	C-A

Variable-salinity Oyster Reef Assemblages (continued)

Gastropoda	
Crepidula plana	O-C
Crustacea	
Balanus eburneus	C
Balanus amphitrite	O-C

Variable-salinity Non-reef Assemblages (10 - 30 °/oo)

Pelecypoda	
Nuculana acuta	R-O
Nuculana concentrica	C
Mulina lateralis	A
Tagelus plebius	C
Ensis minor	C
Gastropoda	
Retusa canaliculata	R-O
Echinodermata	
Amphiodia limbata	C

Intermediate-salinity Inshore Coastal Assemblages (20 - 40 °/oo)

Pelecypoda	
Aequipecten irradians	A
Trachycardium muricatum	A
Mercenaria mercenaria	A
Chione cancellata	C-A
Tagelus divisus	A
Gastropoda	
Nassarius vibex	C
Neritina virginea	R-O
Melampus bidentatus	C

Intermediate-salinity Inshore Shallow Water Assemblages (20 - 40 °/oo)

Pelecypoda	
Abra aequalis	A
Corbula contracta	C
Diplodonta punctata	R-O
Mulina lateralis	A
Nuculana concentrica	C
Pandora trilineata	R-O
Periploma fragile	R-O

Intermediate-salinity Inshore Shallow Water Assemblages (continued)

Gastropoda

Nassarius acutus	C
Retusa canaliculata	O-C

High-salinity Oyster Reef Assemblages (34 - 45 °/oo)

Pelecypoda

Anomia simplex	C
Brachidontes exustus	C
Diplothyra smithi	O
Ostrea equestris	A

Gastropoda

Anachis avara	C
Anachis obesa	C
Mitrella lunata	C
Thais haemostoma floridana	O-C

Crustacea

Crangon heterochelis	C
Menippe mercenaria	O

High-salinity Non-reef Assemblages (34 - 45 °/oo)

Pelecypoda

Amygdalum papyria	C
Anomalocardia cuneimeris	A
Laevicardium mortoni	C
Phacoides pectinatus	R-O
Pseudocyrena floridana	C

Gastropoda

Bittium varium	A
Caecum pulchellum	C
Cerithidea pliculosa	C
Cerithium variabile	C
Haminoea succinea	R-O
Modulus modulus	R
Tegula fasciata	R-O
Vermicularia fargoi	C

Inshore/nearshore Inlet and Pass Assemblages

Pelecypoda	
Atrina seminuda	R-O
Crassinella lunulata	C
Lucina amiantus	C
Lucina crenella	C
Tellidora cristata	C
Gastropoda	
Anachis avara	R-O
Polinices duplicatus	C
Sinum perspectivum	R-O
Scaphoda	
Dentalium texasianum	O-C
Echinodermata	
Arbacia punctulata	O
Hemipholis elongata	R-O
Luidia clathrata	O
Mellita quinquiesperforata	C
Ophiolepis elegans	C
Coelenterata	
Astrangia astreiformis	C
Crustacea	
Dromidia antillensis	R-O
Heterocrypta granulata	R-O

Nearshore and Offshore Facies

Intertidal Surf Zone

Pelecypoda

Donax variabilis variabilis	A
Donax variabilis texasiana	A
Donax tumida	C

Gastropoda

Olivella mutica	C
Terebra cinerea	A

Crustacea

Emerita talpoida	A
Ocypode albicans	C

Constant-salinity Littoral Zone

Pelecypoda

Atrina serrata	C
Chione intapurpurea	C
Dinocardium robustum	C
Dosinia discus	C
Dosinia elegans	R
Labiosa plicatella	R-O
Solen viridis	C
Spisula solidissima	C
Tellina tayloriana	A

Gastropoda

Architectonica nobilis	C
Busycon plagiosum	C
Oliva sayana	C
Phalium granulatum	C
Terebra dislocata	A

Echinodermata

Luidia clathrata	C
Mellita quinquiesperforata	A

Variable-salinity Littoral Zone (15 -36 °/oo

Pelecypoda

Abra lioica	A
Macoma tageliformis	C
Mulina lateralis	C-A
Nuculana concentrica	C

Variable-salinity Littoral Zone (continued

Gastropoda

Anachis avara	C
Nassarius acutus	C
Polinices duplicatus	C

Crustacea

Portunus gibbesi	O-C
Squilla empusa	C-A

Offshore Littoral Zone - Soil or Mud Bottom

Pelecypoda

Nucula proxima	C
Nuculana concentrica	C
Pandora bushiana	C
Pitor cordara	C
Varicorbula operculata	A

Gastropoda

Anachis saintpairiana	A
Nassarina glypta	C
Nassarius ambiguus	C

Offshore Littoral Zone - Sandy Bottom

Pelecypoda

Aequipecten gibbus	C
Aequipecten mucosus	C
Chione clenchi	A
Chione grus	C
Gouldia cerina	A
Laevicardium laevigatum	R-C
Lucina sombrerensis	C
Pecten raveneli	R
Phylloda squamifera	C
Quadrans lintea	C
Semele purpurescens	C
Solecurtus cumingianus	R-O
Tellina georgiana	C

Gastropoda

Antilliphos candei	C
Distorsio clathrata	C
Murex fulvescens	C
Murex pomum	C
Strombus alatus	R-O
Tonna galea	R-O

Figure 3.2

Representative habitats illustrating faunal successions in the inshore and near shore environments.

1. Freshwater/brackish biotope (0 - 5 °/oo)
2. Low-salinity biotope (0 - 10 °/oo)
3. Intermittent variable-salinity biotope (5 - 30 °/oo)
4. Variable-salinity oyster reef biotope (10 - 30 °/oo)
5. Variable-salinity non-reef biotope (10 - 30 °/oo)
6. Intermediate-salinity inshore coastal biotope (20 - 40 °/oo)
7. Intermediate-salinity inshore shallow water biotope (20 - 40 °/oo)
8. High-salinity oyster reef biotope (34 - 45 °/oo)
9. High-salinity non-reef biotope (34 - 45 °/oo)
10. Inshore/nearshore inlet and pass biotope
11. Intertidal surf zone
12. Constant-salinity littoral zone
13. Variable-salinity littoral zone
14. Offshore littoral zone - soil or mud bottom
15. Offshore littoral zone - sandy bottom

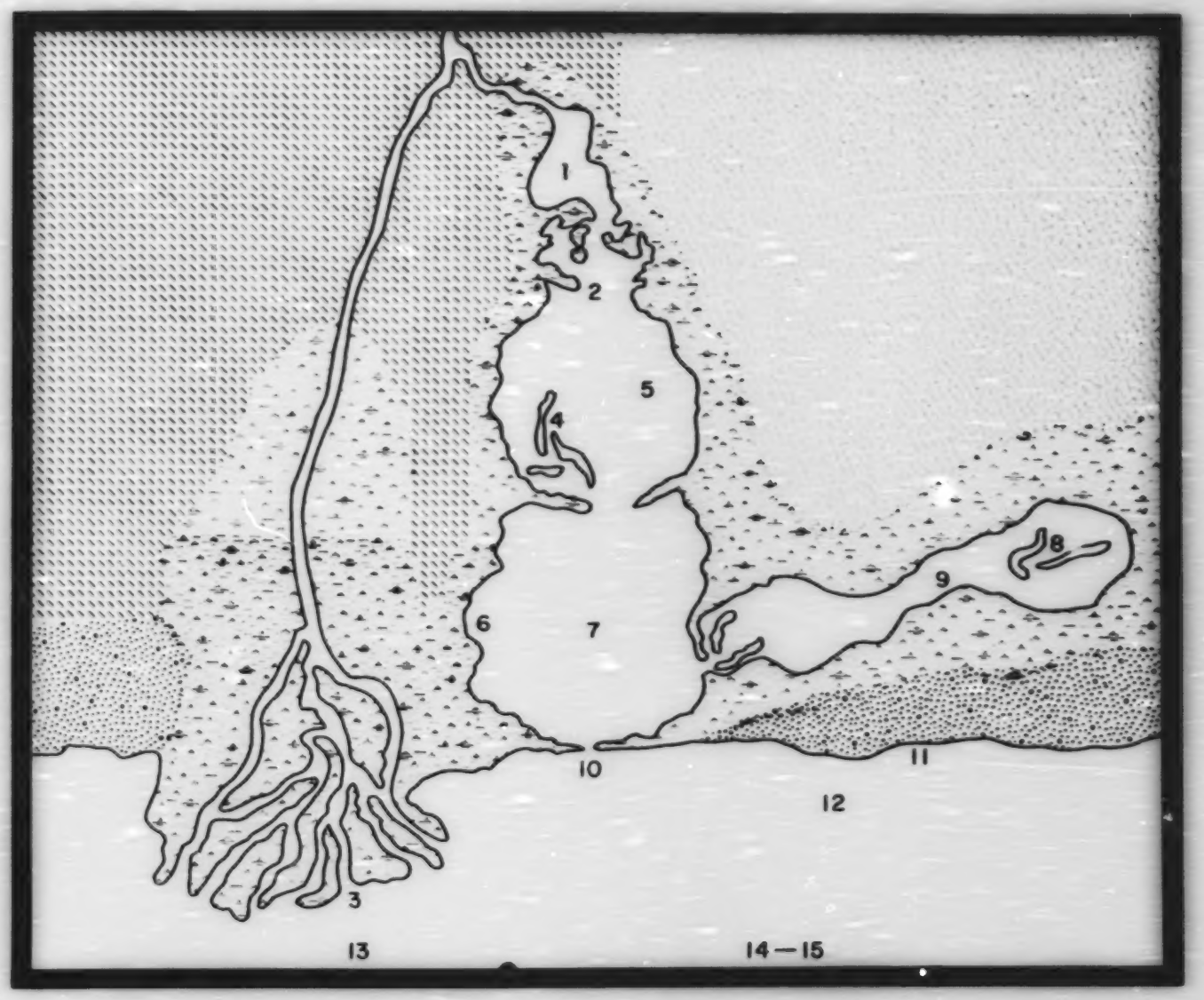

Figure 3.2 Representative habitats illustrating faunal successions

4.0 Data Analysis

The analysis of data collected in the three post-spill studies and from literature sources is discussed in this section. To the extent data limitations permit, analytical studies were performed in an attempt to identify the fate and effects of the crude oil spilled as a result of the Shell Incident in December of 1970.

The Gulf Coast area is dynamic both physically and biologically, and does not lend itself to easy determination of the existance of environmental stresses. This is further complicated by the extensive development of the area in petroleum production. Within the constraint of such a system, this study was conducted to determine deviations from normal conditions within the area of the spill which first identifies anomalies and then correlates these anomalies to the existance of crude oil within the water column, sediments, and the biota.

Shortly after the spill incident, Texas Instruments conducted a remote sensing and oceanographic survey in the vicinity of Shell Platform B.

The areal survey which was made between January 10-17, 1971 used ultraviolet and infrared imagery. The first survey utilized ultraviolet imagery only and mapped areas of slick (6.2 square miles), rainbow (8.6 square miles) and sheen (22.2 square miles). Three days after the first survey the area was again flown and the oil spill area mapped with only infrared imagery showing a total area of spill of 4.9 square miles and 42.8 linear miles of oil stringers. Thus, the conclusion was reached by Texas Instruments that the infrared detects primarily oil slick whereas the ultraviolet detects all of the oil spill material that is present, be it slick, rainbow or sheen.

The surveys conducted by Texas Instruments from January 10 through 17, 1971, and supplemented by visual observations for January 10, establish that spilled oil movements for this period were mostly in a northeasterly direction with some movement to the north and southwest but, in no instance across transect stations beyond the two (2) mile station on the south transect.[1]

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1. See report entitled "OCEANOGRAPHIC AND REMOTE SENSING SURVEY IN THE VICINITY OF THE SHELL SPILL, GULF OF MEXICO", January 1971, prepared by Texas Instrument, Inc., under Contract no. 68-01-0017, and dated 25 March 1971.

The reported locations and concentrations of pollutants is presented in Figures 4.1, 4.2, 4.3, and 4.4 which have been extracted from the report prepared by Texas Instruments, Incorporated. The results of the remote sensing overflight experiment indicate that such devices can yield valuable data for both predictive and historical purposes.

The flights represented only a portion of the airborne surveilance of the incident in that daily flights by USCG-EPA-USGS-Shell mapped the oil slick and showed that during the incident "the oil was moved in every direction" from the Platform.

4.1 Hydrocarbons in Living Organisms and Natural Sediments

Hydrocarbons found in natural recent sediments were derived from the components of former living things. As the sediment matures, the composition of the organic debris changes. Some of the major compounds from the biotic matter are partially or completely eliminated while other compounds of little importance in the life cycle of organisms become enriched.

A new group of compounds which are generally absent in organisms can be generated as the result of action of microbes and/or inorganic processes. It should be noted that anaerobic conditions at the water-sediment interface is preferred, if not prerequisite, to the preservation of the organic matter contributed to the sediments. In the presence of oxygen, hydrocarbon-oxidizing bacteria would make short work of the debris. If oxygen is absent the hydrocarbons are preserved and part of the non-hydrocarbon organics can be transformed by anaerobes into hydrocarbons. Recent analysis of food materials from the sunken and recovered research submarine ALVIN indicate that microbial degradation is 10 to 100 times slower at greater depths even in the presence of adequate oxygen.

As early as 1954, it was substantiated that liquid paraffinic, naphthenic and aromatic hydrocarbons were present in recent sediments in a variety of salty, brackish and freshwater deposits. There are conflicting views on the general natural concentration of hydrocarbons in sediments, with reported ranges of a few tenths of hundredths ppm to a range of 9 to 11,700 ppm. Degens, in 1965, reported that a 300 ppm hydrocarbon concentration found in an ancient shale is 5 to 10 times higher than recent sediments. From these data a normal level of 30 to 60 ppm may be extrapolated as a reasonable natural range. However, because the study area is located in a highly developed oil production area with continuing minor spillage and seepage, the pre-spill levels probably exceed the normal levels of 30 to 60 ppm, which is not, therefore, used for analytical purposes.

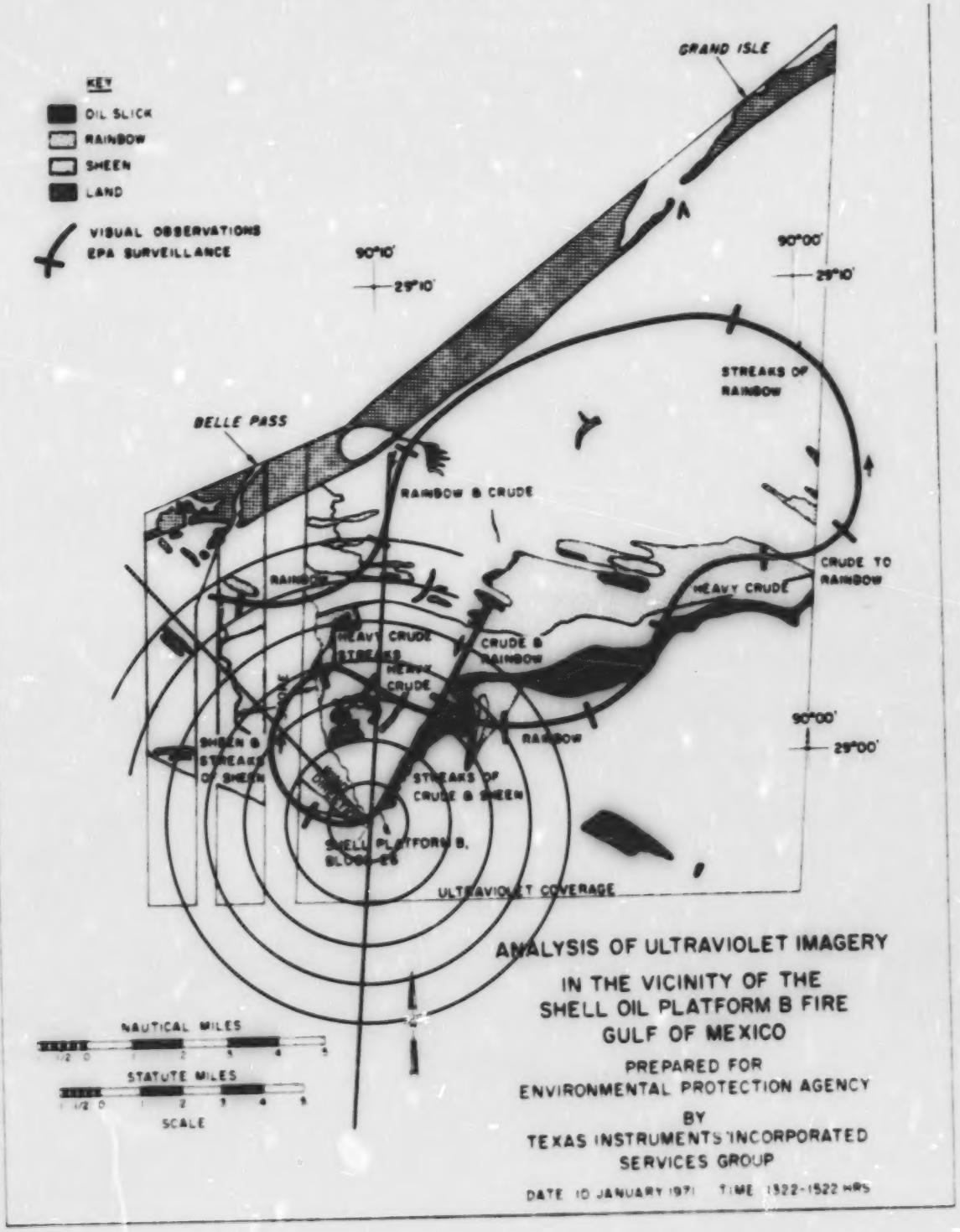

Figure 4.1 Comparison of UV Analysis and Visual Observation in Vicinity of Shell Platform B

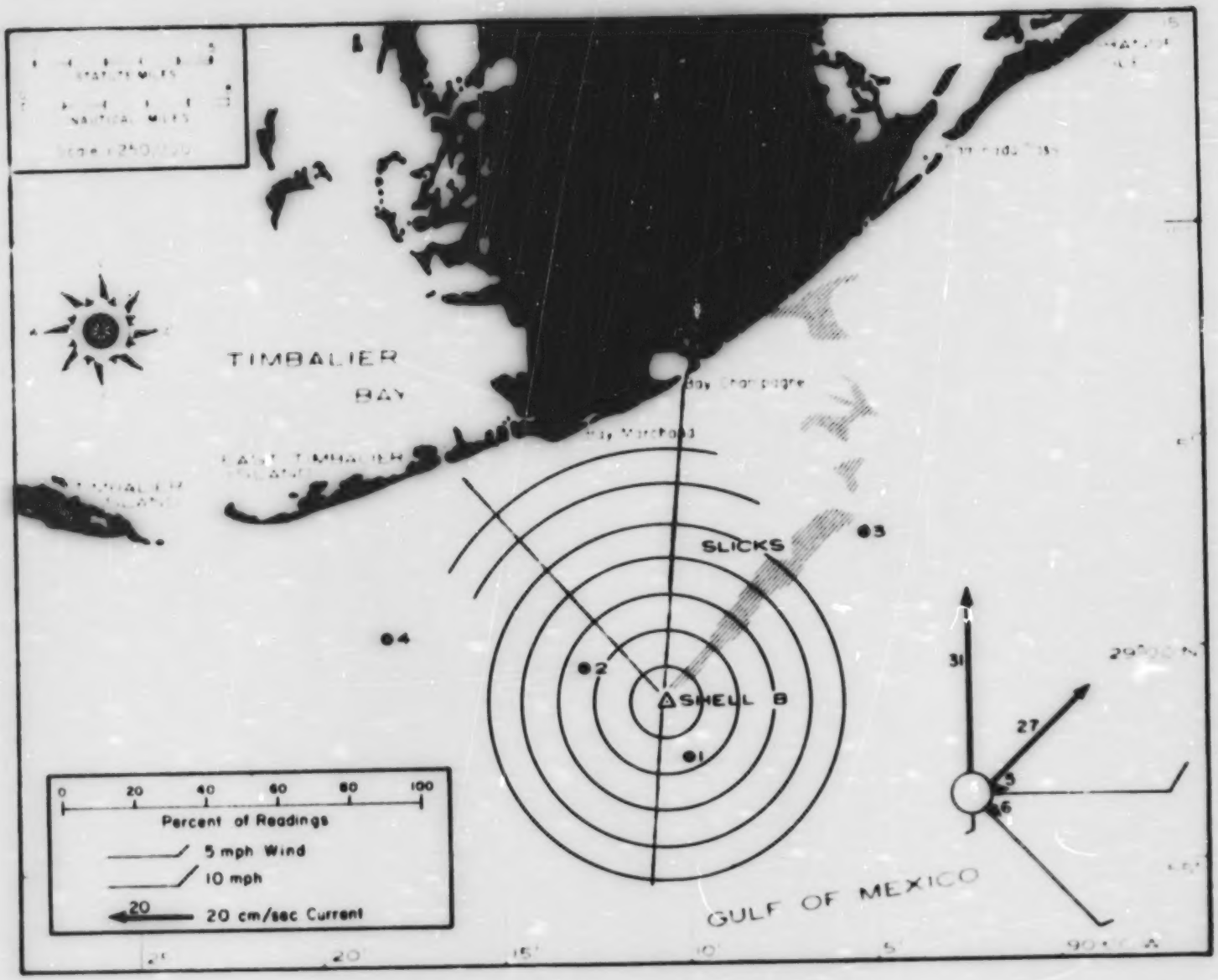

Figure 4.2 Current and Wind Data and Oil-Slick Orientation, 13 January 1971, Texas Instruments Surveillance

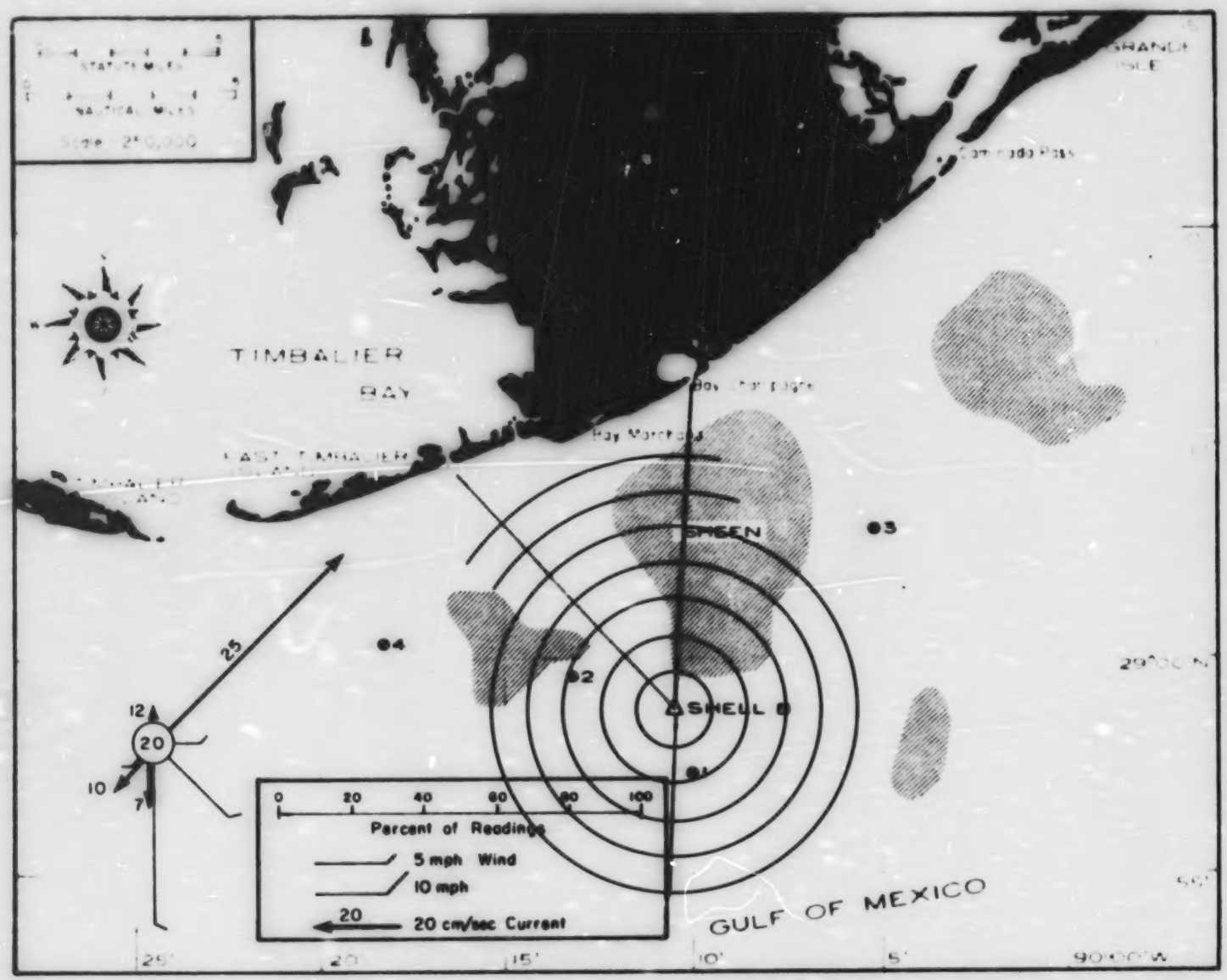

Figure 4.3 Current and Wind Data and Oil-Slick Orientation, 14 January 1971, EPA Spill Surveillance

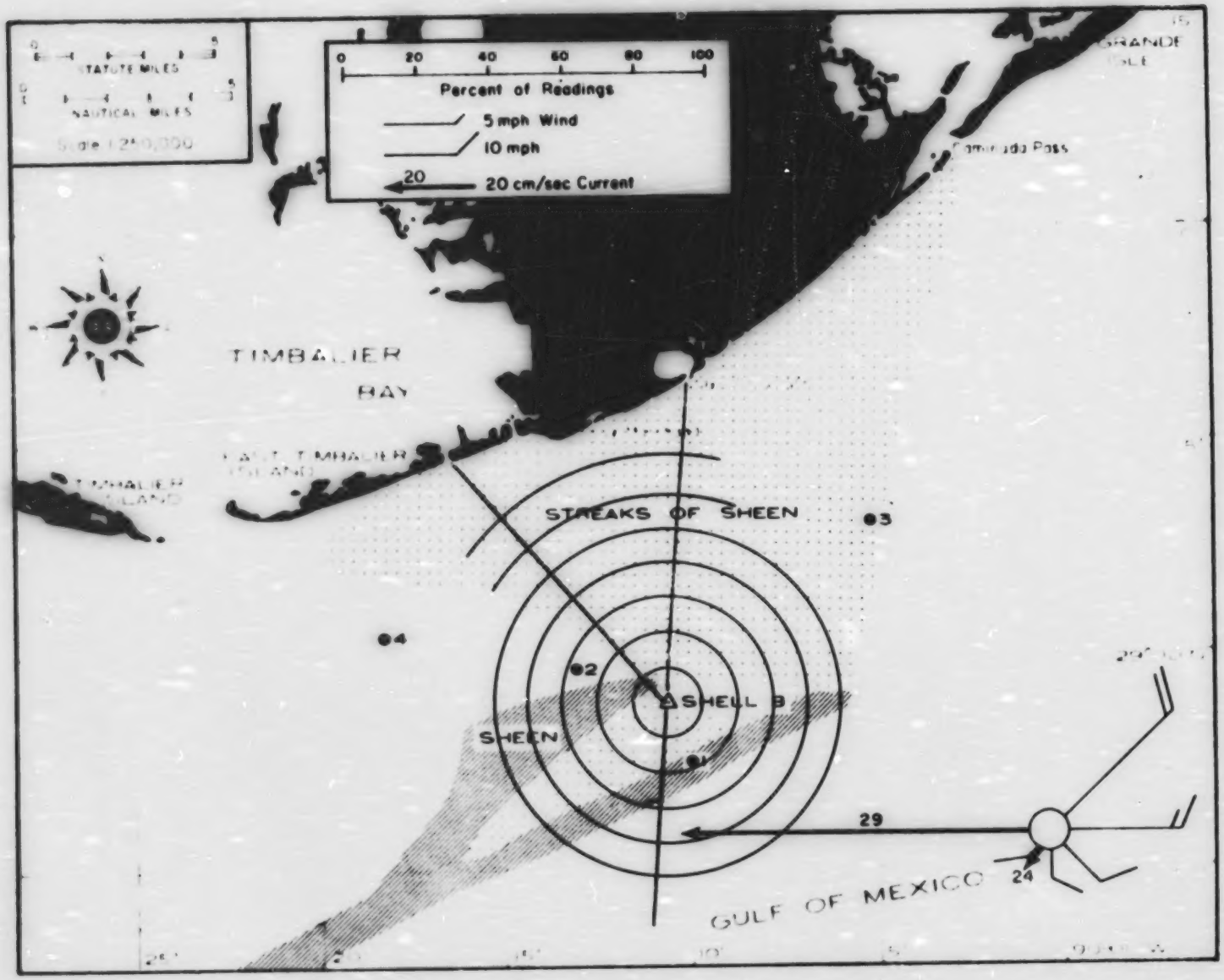

Figure 4.4 Current and Wind Data and Oil-Slick Orientation, 16 January 1971, EPA Spill Surveillance

Present day organisms and natural recent sediments lack light hydrocarbons in the C_3 to C_{14} range. In the C_{15} range, normal recent sediments show a marked preference of odd numbered over even numbered paraffins, probably resulting from the preferential oxidation of even numbered hydrocarbons by microbes.

Preference varies widely in living organisms. Petroleum paraffins exhibit no odd or even preference in the C_{15} + range and the hydrocarbons in the C_3 to C_{14} range are not only present but constitute 50% of the avera e crude.

Saturated hydrocarbons from C_1 to C_{50} make up a substantial fraction of crude oils as do the naphthalenes and aromatic hydrocarbons. The lowest molecular weight n-alkane reported in plants is n-heptane (C_7 H_{16}) and the heaviest reported is n-dohedracontane (C_{62} H_{126}). It is obvious that hydrocarbons are much more universally distributed in nature than was previously thought. They are synthesized by most if not all organisms and certain compounds are stable to the extent that they can be used to determine feeding habits and ranges of some fishes and mammals.

Distinction between oil and natural hydrocarbons requires careful detailed analysis of the characteristic differences in molecular size and type distribution. Crude oils are wide range mixtures containing molecules of different sizes in fairly even distribution while organisms are limited to certain biogenic pathways which produce hydrocarbons in preferred size ranges.

4.1.1 Distribution and Ecological Significance of Observed Hydrocarbons

4.1.1.1 Water-Disperable Hydrocarbons

Examinations of sediments and waters near Shell Platform B, Block 26, reveal that water-dispersable hydrocarbons have been dissipated from the sediments immediately surrounding the subject platform (reference Figure 4.5).[1] These data indicate that no seepage of oil from the incident location occurred for some time prior to these investigations. The exact time cannot be estimated because of the absence of information related to dissipation rates. There can be little doubt, however, that water-dispersable fractions (probably aromatic compounds) from the crude oil were transported through the water column and deposited in sediments even at considerable depths (60' observed). These deposits appear to become rapidly redispersed into the overlying waters. Results of this study indicate that significant residuals of these dispersable hydrocarbons remain in the sediment for some time prior to their redispersal. This depostion and redispersal is discussed in later portions of this report.

Many data from these analyses repeatedly verified that water-dispersable fractions of crude oil from this spill found their way to the sediments underlying the oil slicks and sheens. A clear example of this vertical dispersion was observed in association with the oil sheen observed 4 to 6 miles north and northwest of Platform B. The vertical dispersion and deposition of water-dispersable hydrocarbons in sediments is shown in Figure 4.5 on the N and NW transects. Variations in sediment hydrocarbon concentrations indicate the sheen was progressing from south to north in response to prevailing winds.

In Figure 4.5, North Transect, at miles 2 through 4, it is noted that increased sedimental water-dispersable hydrocarbons were observed and to mile 7 where the absence of similar data occurred across the northermost front of the sheen. After passage of the sheen, a rapid dissipation back to the water apparently occurred, indicated by decreased sedimental water-dispersable hydrocarbons from miles 6 to 5, 5 to 4, and 4 to 3.

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1. Data discussed and presented are limited to these data acquired by sampling during the period from June 1-10, 1971. No baseline data are available and samples taken during earlier studies of the area (Dec 1970) showed anomalies attributable to the effects of the spill. See also Appendix II.

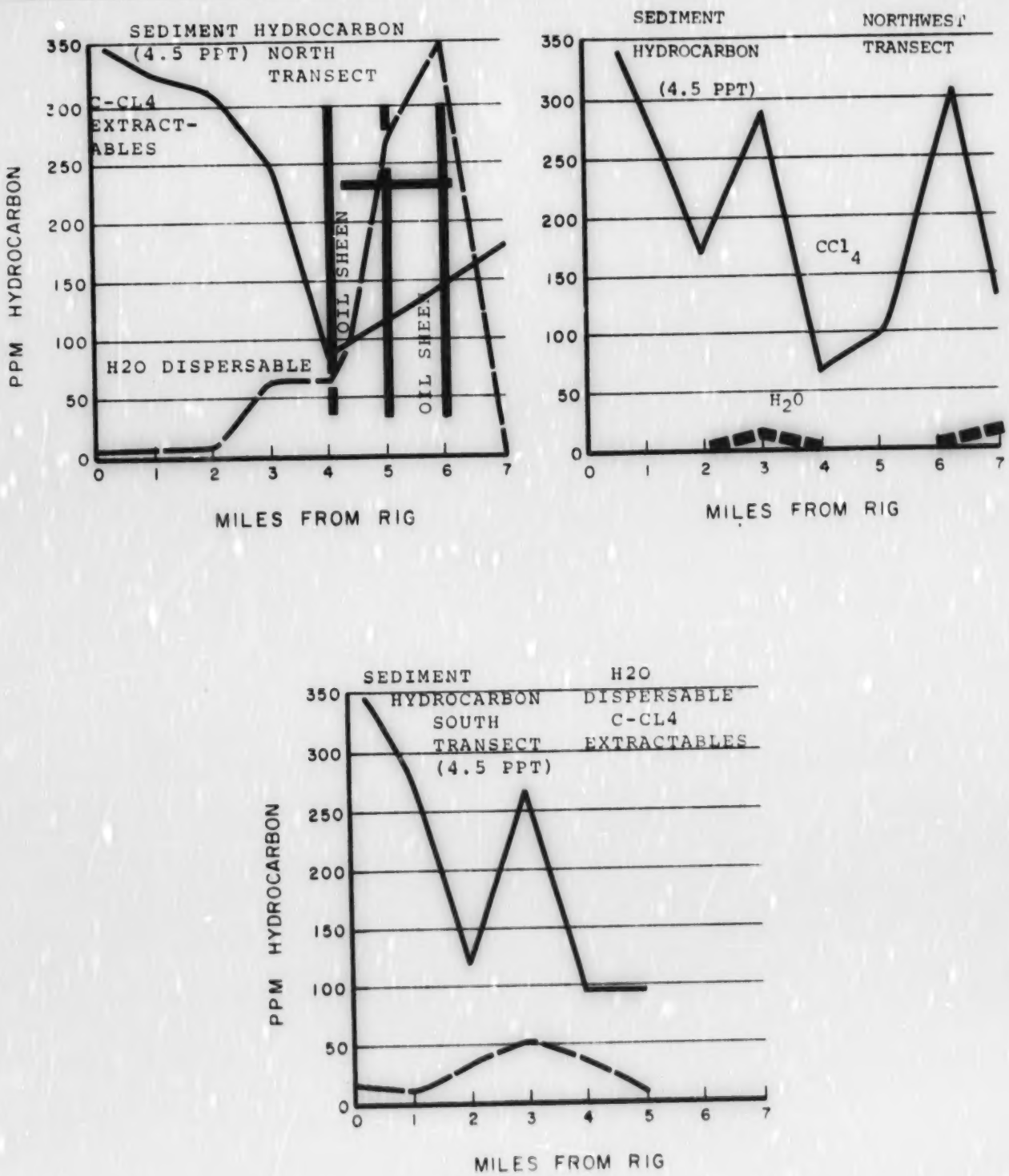

Figure 4.5 Sediment Hydrocarbon

4.1.1.2 Carbontetrachloride Extractable Hydrocarbons (Aliphatic and Isoprenoid Hydrocarbons)

Significant quantities of CCl_4 extractable crude oil fractions reached bottom sediments at depths down to 60'. This fact was revealed through the analyses of sediments near the subject platform where samples were found to contain concentrations which averaged 4.5 ppt compared to about 300 ppm one mile from the platform on all transects. Levels dropped to between 50 and 100 ppm four miles from the platform on all transects. A chromatographic analysis of a sample of crude oil from Platform A revealed that carbon compounds with carbon numbers between 15 and 31 predominated with the highest concentrations occurring in the smaller compounds near and including 15 carbons (Figure 4.6). The major concentrations of crude fractions lie within carbon numbers less than 24 with a comparatively minor distribution above this length.

In the vicinity of the oil sheen as previously discussed sedimental CCl_4 extractables rose rapidly indicating a relatively free movement of these substances through the water column. Likewise, on the south transect, at miles 2 and 3 south of the platform at depths near 60' there was again evidence of significant concentrations of CCl_4 extractables. (These data may have been influenced by quantities of oil dispersants to the extent they may have been used for safety purposes during the "spill"). Consequently the vertical dispersion of both the water dispersable and CCl_4 extractable crude oil fractions may have been unduly augmented by these artificial conditions. These data, the distribution of sediment hydrocarbons south of Platform B, correspond with data presented by Texas Instruments regarding the direction of the movement of oil during the early phases of the incident.[1]

4.1.1.3 Ecological Significance

The water-dispersable components of crude oil probably represent aromatic compounds which have been cited as being more toxic than aliphatic hydrocarbons. These compounds are more soluble in salt water than in fresh water thus increasing their biological

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1. See Texas Instrument Inc. report entitled "Oceanographic and Remote Sensing Survey in the Vicinity of the Shell Spill, Gulf of Mexico, January 1971."

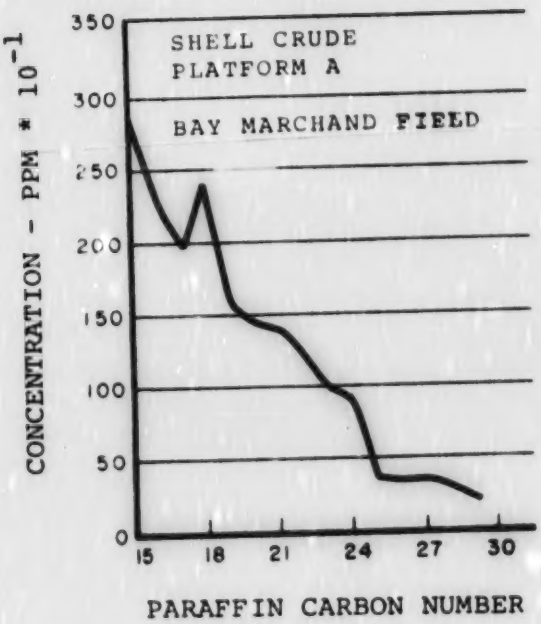

Figure 4.6 Distribution of Carbon Numbers in a Sample of Shell Crude

Figure 4.7 Movement of Spilled Oil

accessibility in the marine environment and hence, their potential toxicity. The apparent cycling of water-soluble and dispersable petroleum fractions from the water column to the sediments and back to the water is therefore potentially damaging to the ecosystem.

Benthic populations may be damaged by these transient materials which, because of their redispersability, may not be detectable a short time later. Likewise, pelagic organisms may be adversely influenced by the above processes since only a fraction of the water-dispersables would ultimately reach the sediments and be deposited. The remaining water-borne fractions would then constitue a significant level in the water column, 1.3, ppm total hydrocarbons were measured from bottom water samples taken near the sheen area while concentrations near zero were found in similar samples three miles south of the sheen.

A comparison of Figure 4.6 with Figure 4.8 reveals a preference of "uncontaminated" megafauna for aliphatic hydrocarbon compounds from 22 through 30 carbons in length. This distribution corresponds closely with the data cited earlier in Section 3.0. Analysis of these data also revealed that organisms of different types tend to reflect the same aliphatic hydrocarbon background levels in the same environment. Note the similarities between the shrimp, crab, oyster, and fish from the same general location on Caminada Bay near Andre Island (Figure 4.9). A definite preference is shown for even numbered short chain hydrocarbons 16, 18, 20, and 22 carbons in length. The odd numbered carbon chains were almost entirely absent in these organisms presenting two distinct possibilities: (1) the odd numbered hydrocarbon chains are not absorbed by endemic organisms, or, (2) they are degraded by the organisms in such a way as to yield even numbered chains. Insufficient data are available at this time for a definitive answer to this question.

These data do not relate directly to the offshore spill but are considered significant since they will prove valuable in future fate and effects studies. Based upon a literature survey and this study, it now appears that the significant aliphatic hydrocarbon chain lengths lie between 15 and 22 carbons. Shrimp taken between 4 and 6 miles northwest of Platform B were relatively free of hydrocarbons in the 15 to 21 range, indicating their uptake of petroleum products was low or insignificant at the time of sampling (Figure 4.10).

In view of the foregoing discussions concerning the vertical migrations of both water-extractable and CCl_4-extractable petroleum products between the water column and sediments, it is difficult not to recognize that both must come into direct contact with all forms of aquatic life throughout the ecosystem. This supposition is reinforced by data from hydrocarbon analyses of bottom water samples in which levels of 3.8 ppm concentrations were found both near the surface

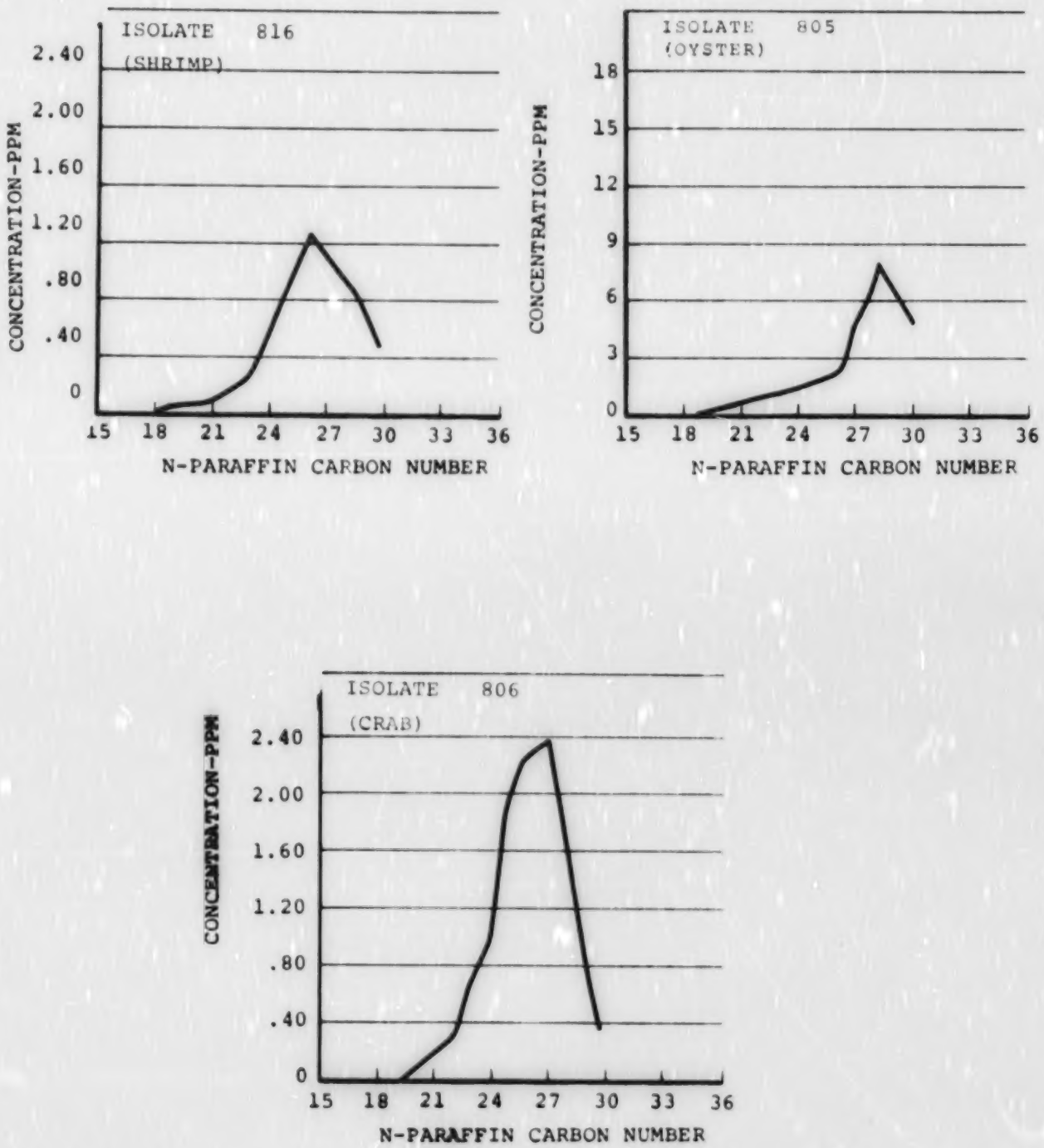

Figure 4.8 Distribution of N-Paraffin Carbon Numbers

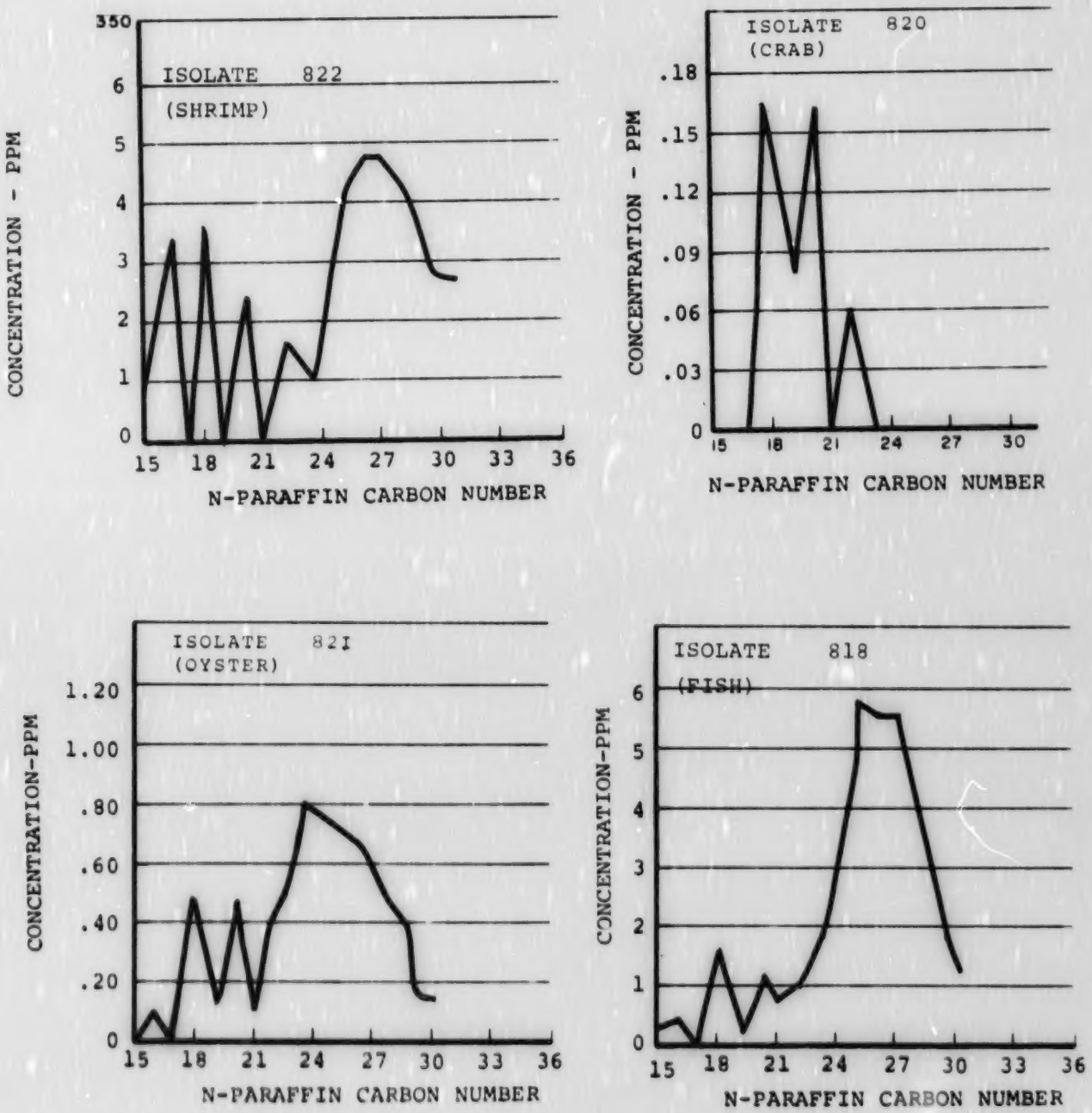

Figure 4.9 Distribution of N-Paraffin Carbon Numbers from Caminada Bay near Andre Island.

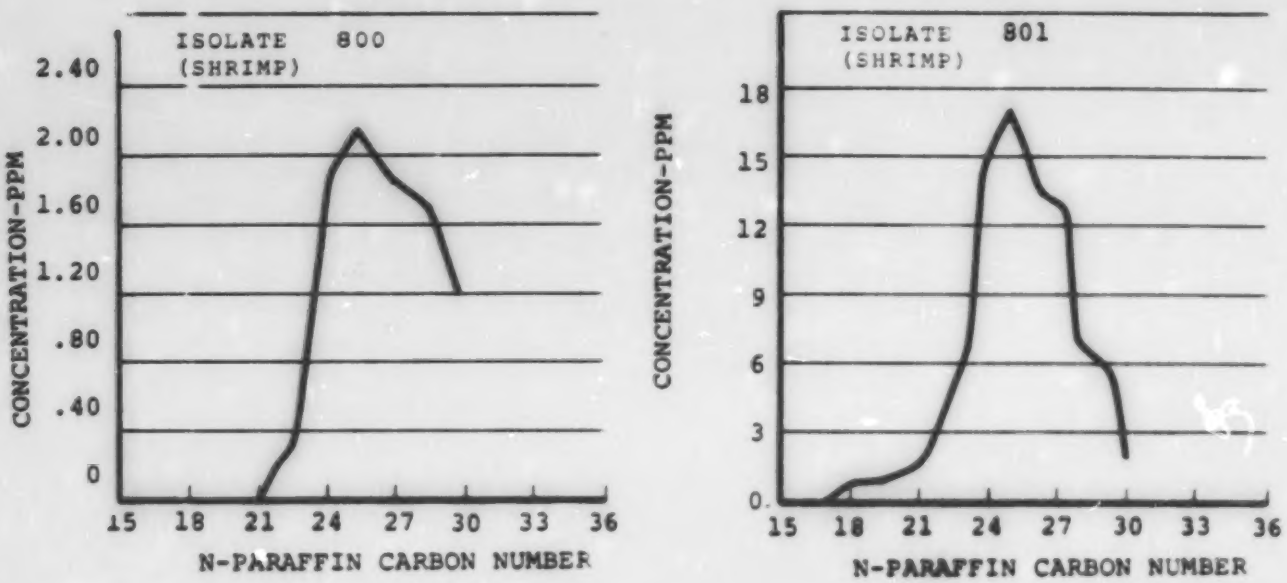

Figure 4.10 Distribution of N-Paraffin Carbon Numbers

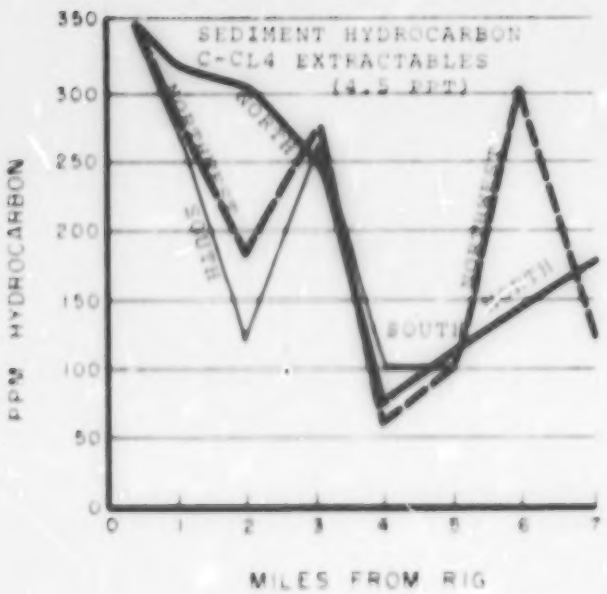

Figure 4.11 Sediment Distribution of Hydrocarbons

and in near bottom waters five miles south and 1.3 ppm hydrocarbons was found in both surface and bottom waters four miles south of Platform B. These data correspond closely with the sediment analysis data presented in Figure 4.11.

4.1.2 Species Diversity

Very poor correlation was observed between Van Veen grab numerical catch data and simple diversity (number of species present as shown in Figure 4.12. No trends could be established between these data and any other parameters. However, a very poorly defined direct relationship appears to exist between dominance diversity (Figure 4.12) and hydrocarbon concentrations in sediments. These data are of questionable significance, however, and must be viewed with caution because of the usual shortcomings of diversity computations.

4.1.3 Distribution of Fauna in the Study Area and Possible Ecological Effects of Hydrocarbons

4.1.3.1 Results of Biological Sampling

Biological sampling near the rig and in adjacent waters was conducted along three distinct transects with samples being taken at one mile intervals. Samples were taken from the sediments by grab sample, off the bottom and just above the bottom by trawl, and near the rig by divers. A survey of the composite catch results for biologically significant organisms may be seen in Figures 4.13 through 4.15. The detailed catch records are contained in Appendix II.

Figures 4.16 through 4.17 delineate the meiofaunal and megafaunal catches. Both meiofaunal and megafaunal organisms appear to show the same numerical trends.

Generally speaking, faunal counts from bottom sampling were uniformly low at stations nearest the rig, comprising 13 X $10^3/m^2$ or less at stations on the one mile radius. Counts along the three transects showed a general numerical increase between the one and two mile stations. The south transect exhibited its highest faunal count at the two mile mark (32 X $10^3/m^2$ organisms). Counts along the north transect reached a maximum of about 48 X $10^3/m^2$ organisms at the four mile mark. Beyond the four mile mark, there was a steady and marked decrease in the number of organisms. At the extreme end of the North transect (nearshore), this decrease may be attributable

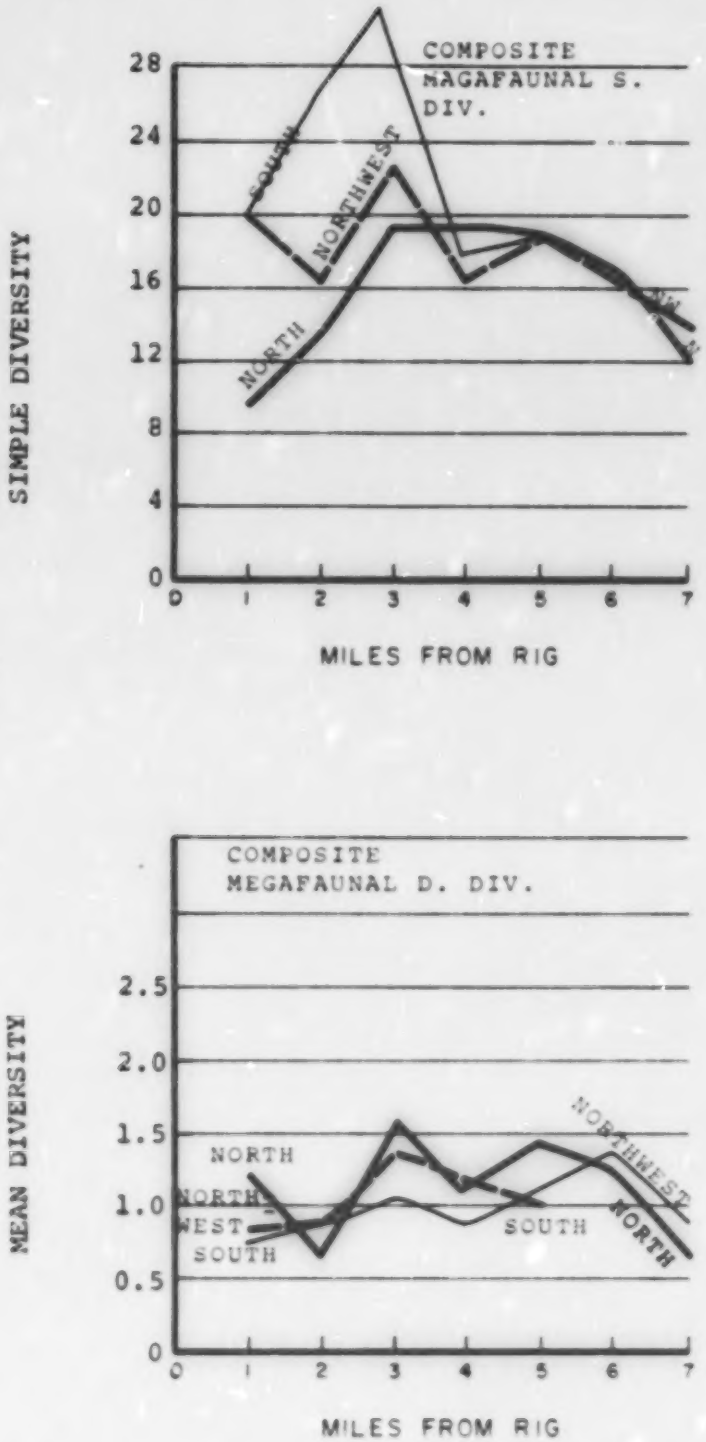

Figure 4.12 Composite Megafaunal Diversity

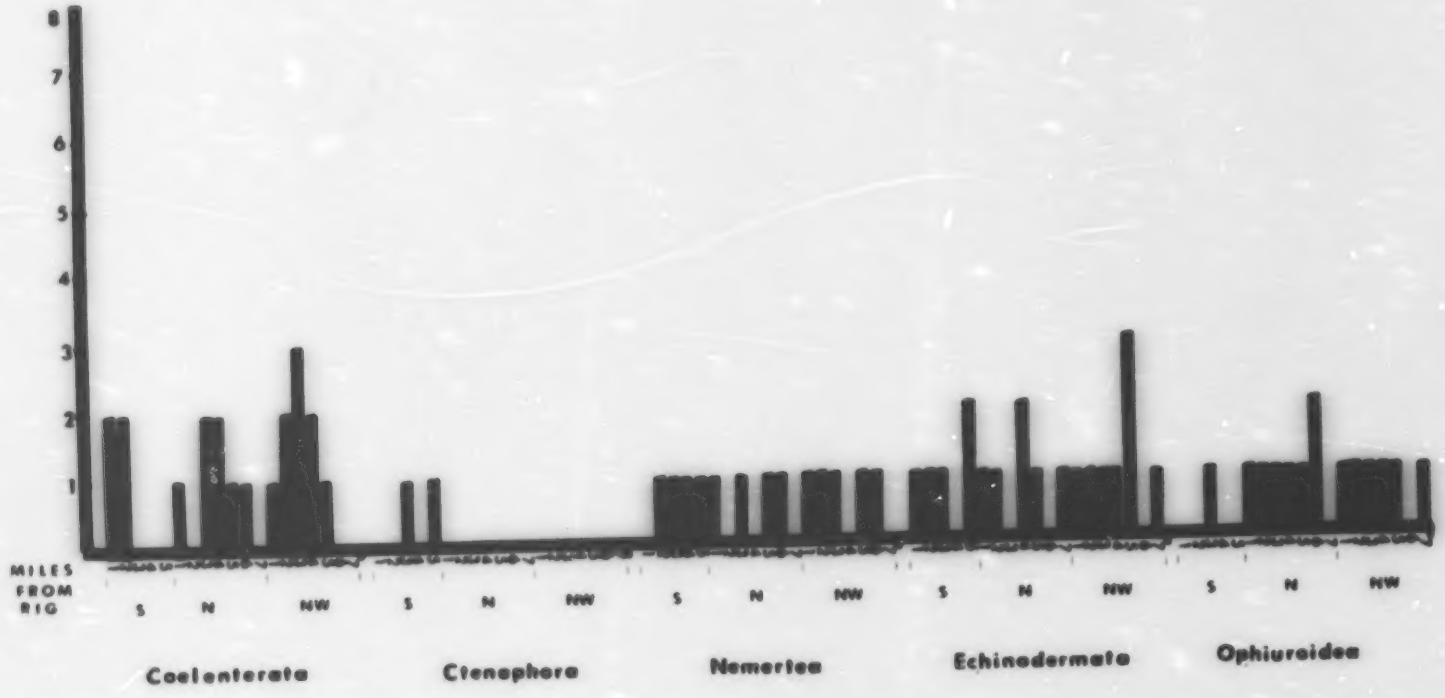

Figure 4.13a Taxonomic Diversity of Invertebrates

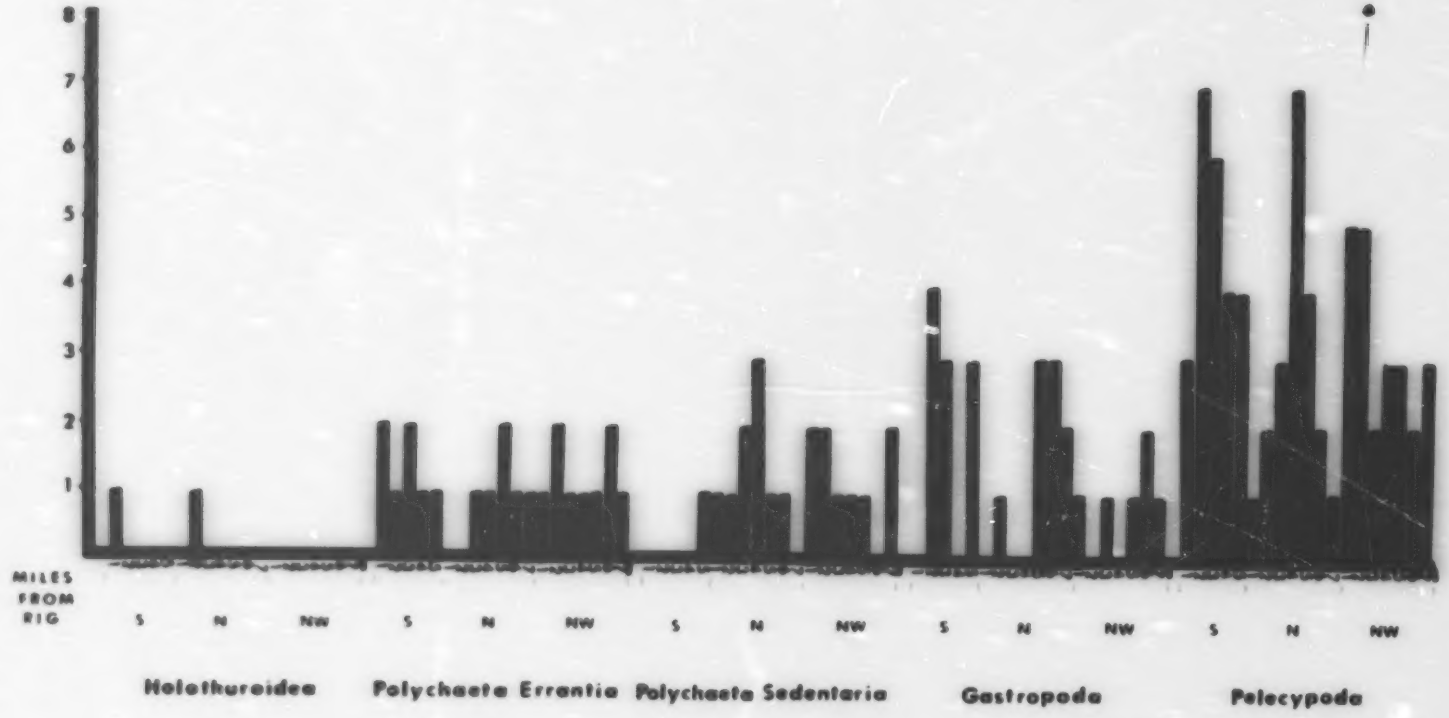

Figure 4.13b Taxonomic Diversity of Invertebrates

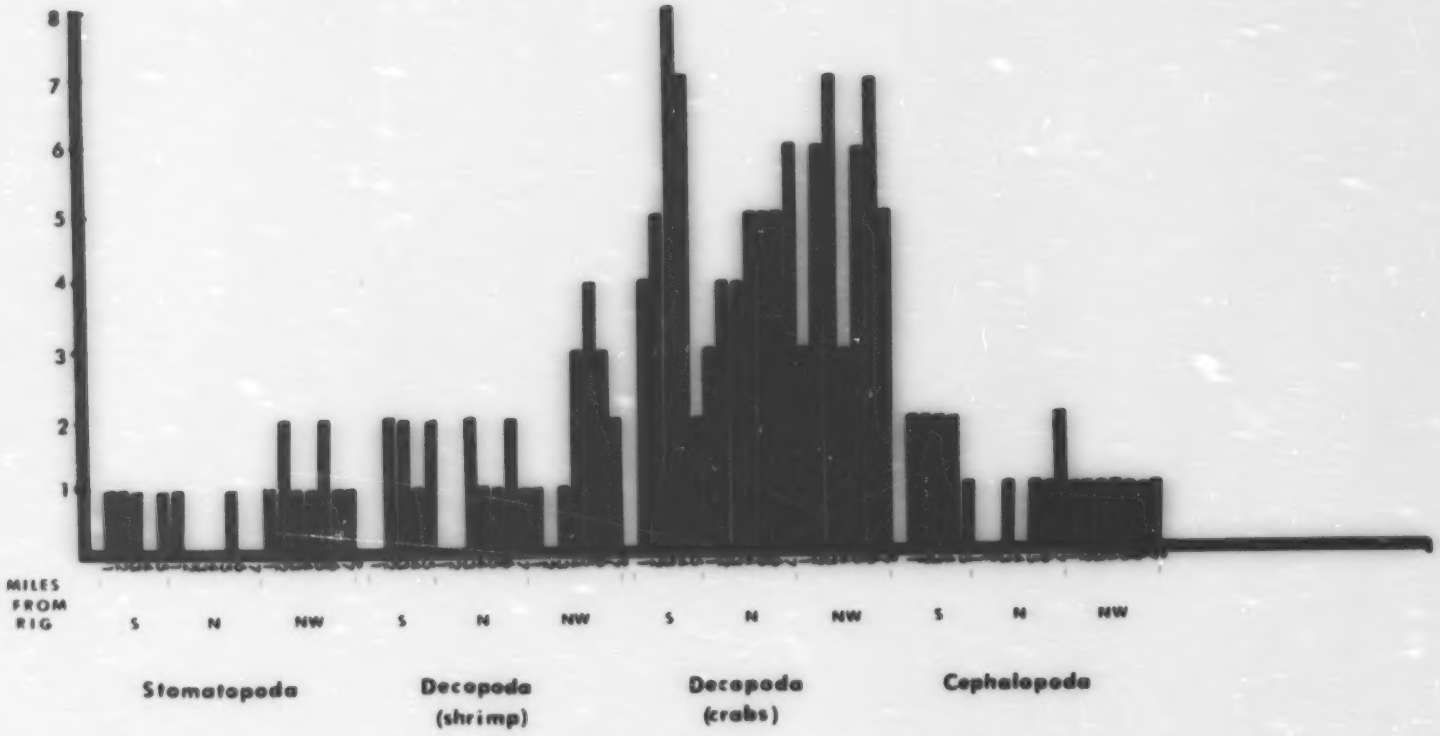

Figure 4.13c Taxonomic Diversity of Invertebrates

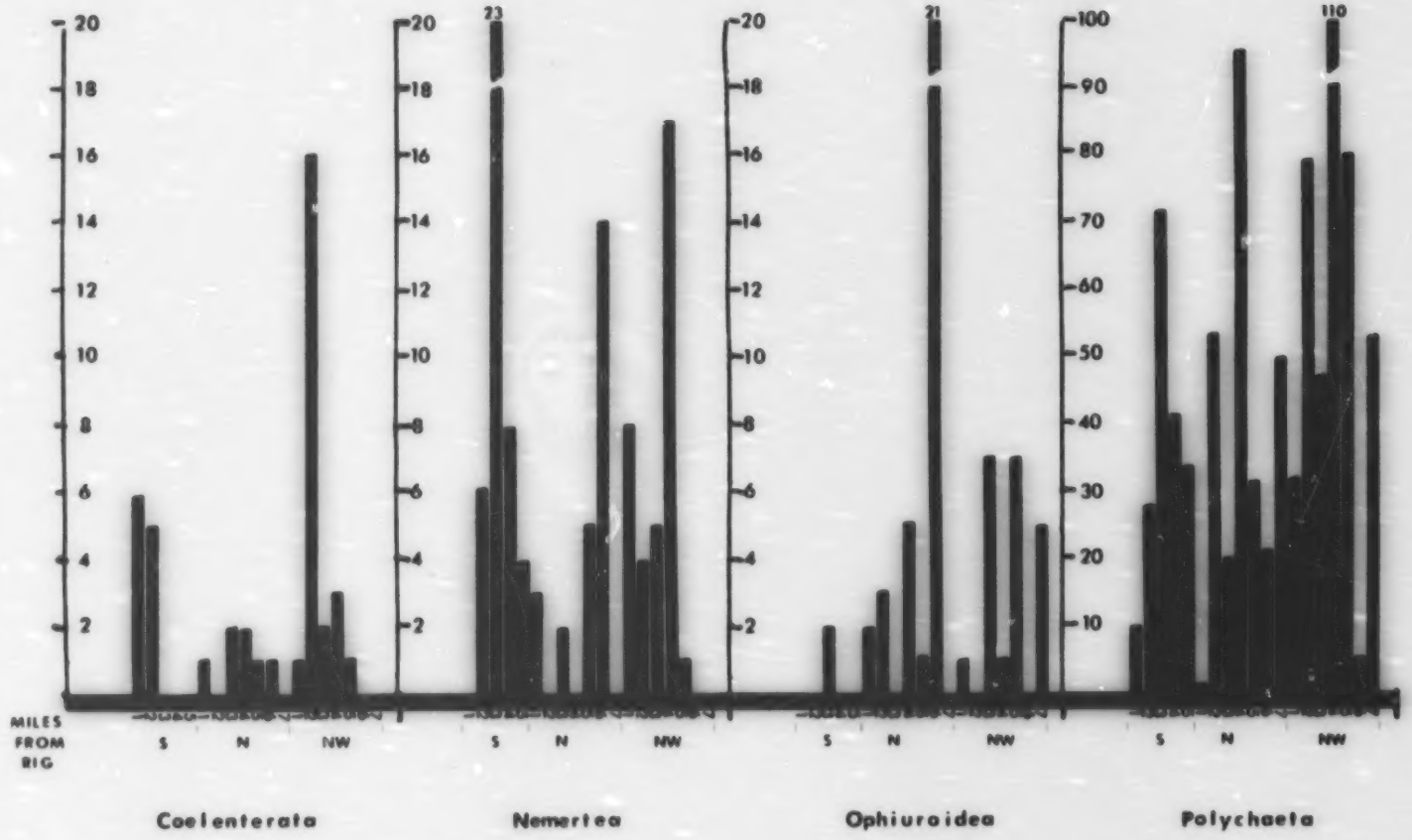

Figure 4.14a Numerical Abundance of Invertebrates
($1/25\ m^2$ Van Veen Grab)

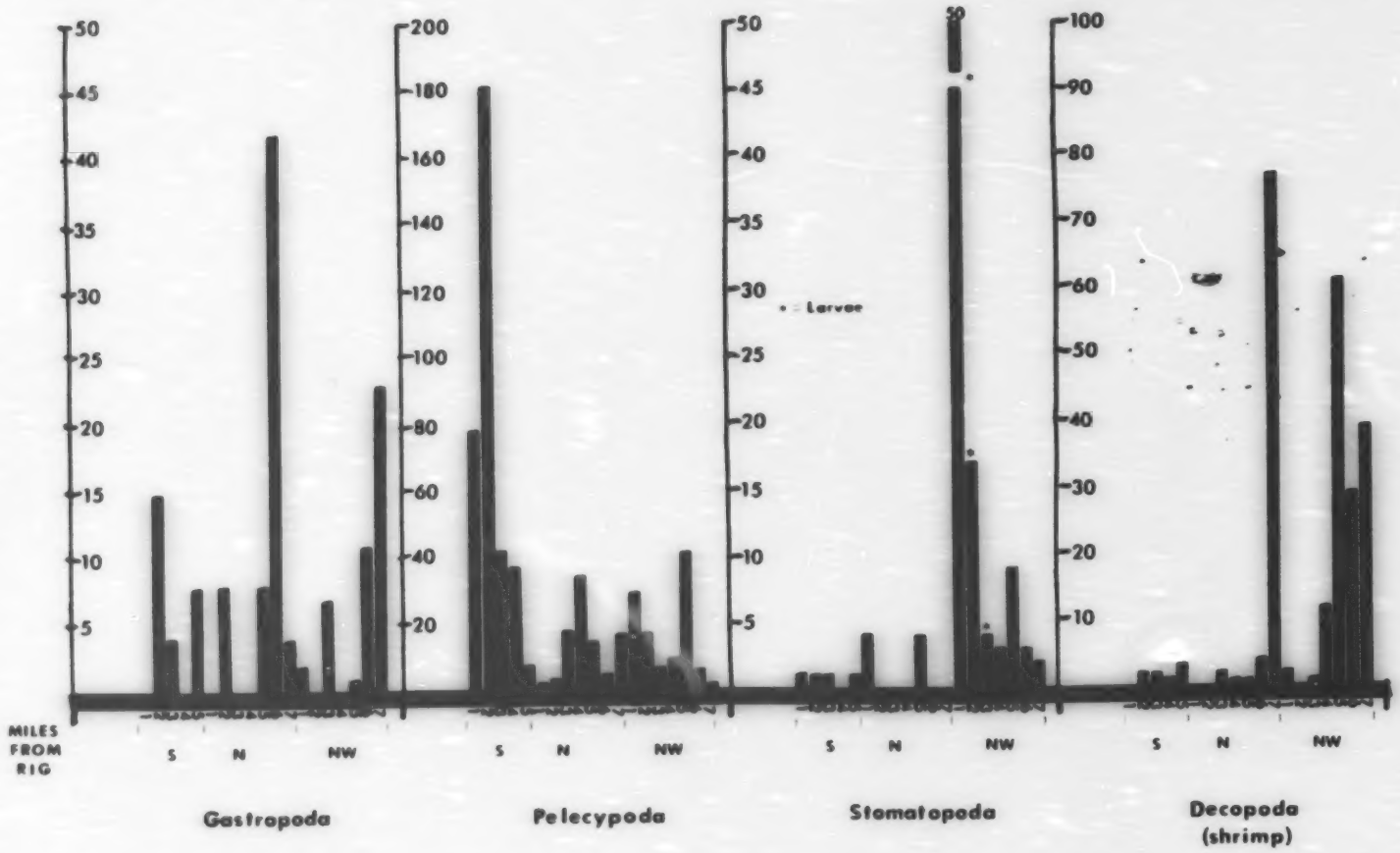

Figure 4.14b Numerical Abundance of Invertebrates ($1/25\ m^2$ Van Veen Grab)

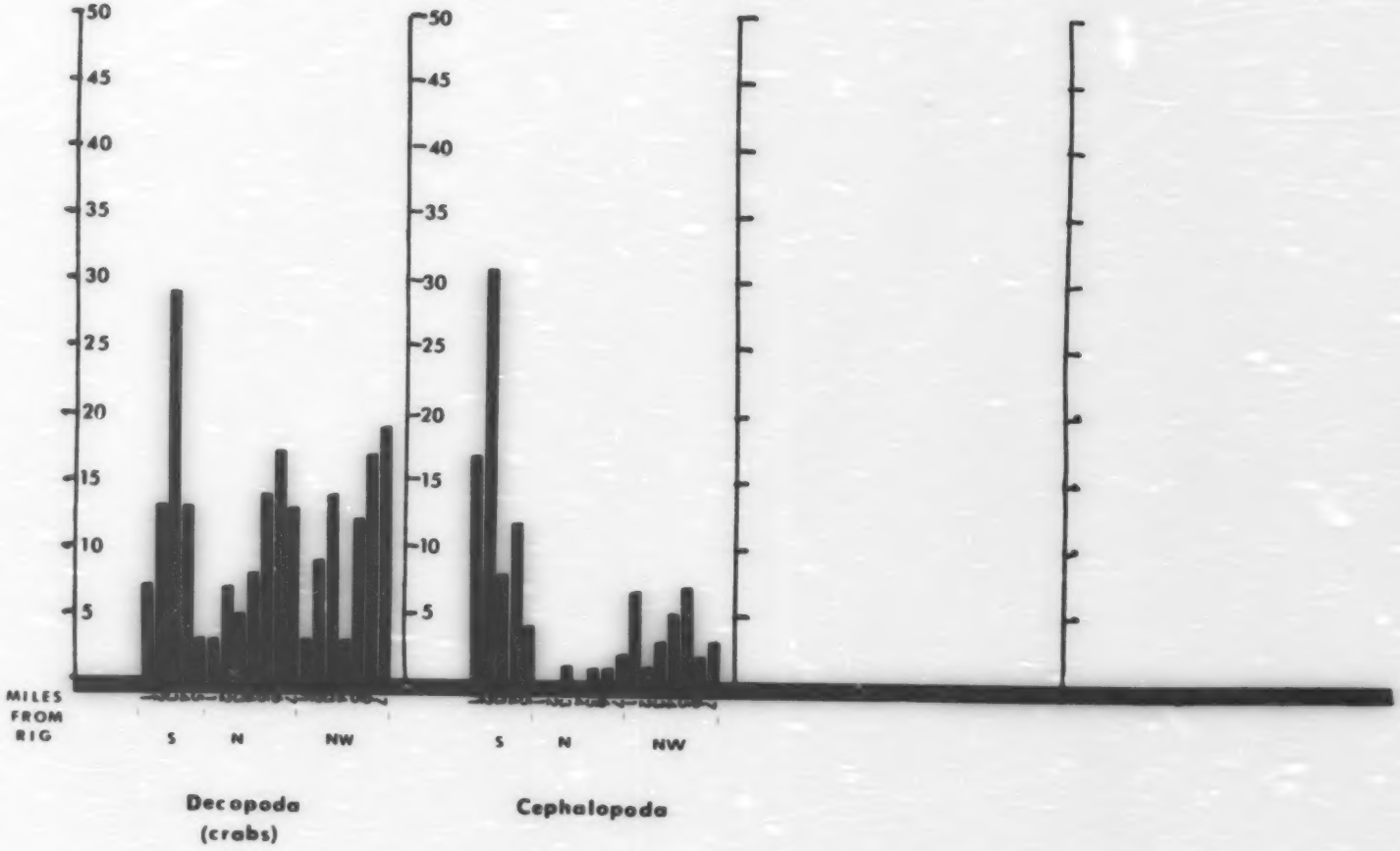

Figure 4.14c Numerical Abundance of Invertebrates ($1/25\ m^2$ Van Veen Grab)

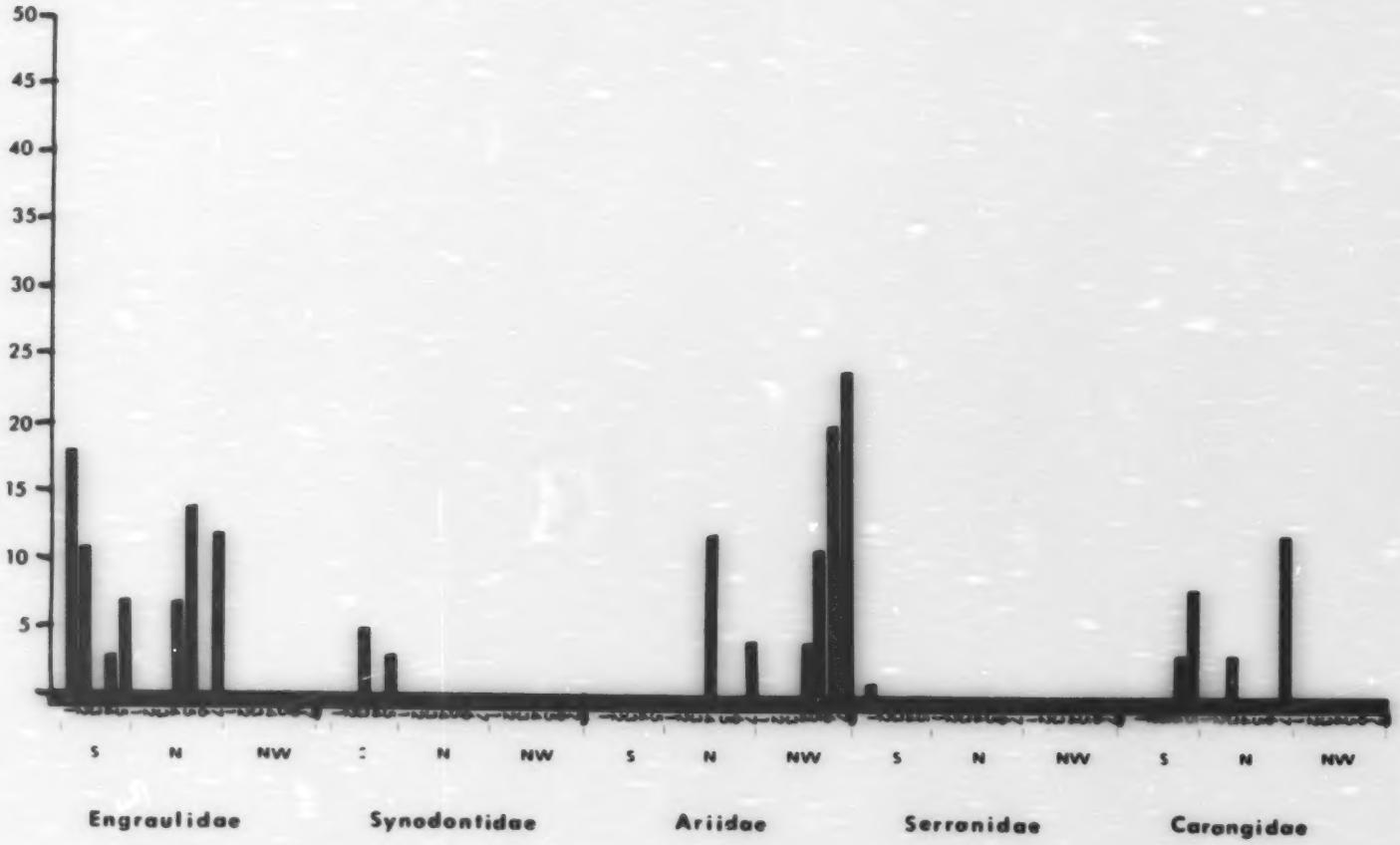

Figure 4.15a Numerical Abundance of Fish (20 min. trawl)

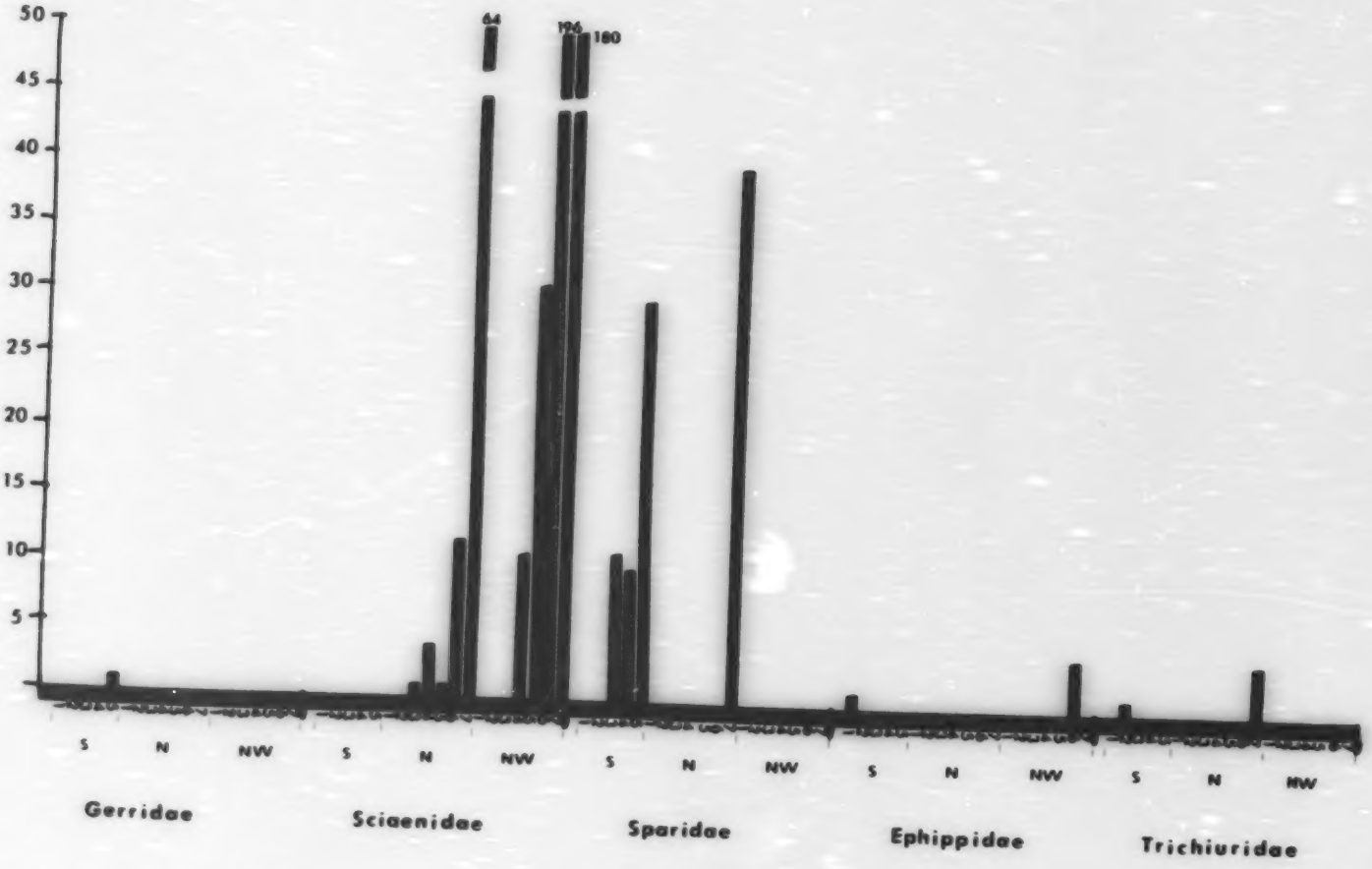

Figure 4.15b Numerical Abundance of Fish (20 min trawl)

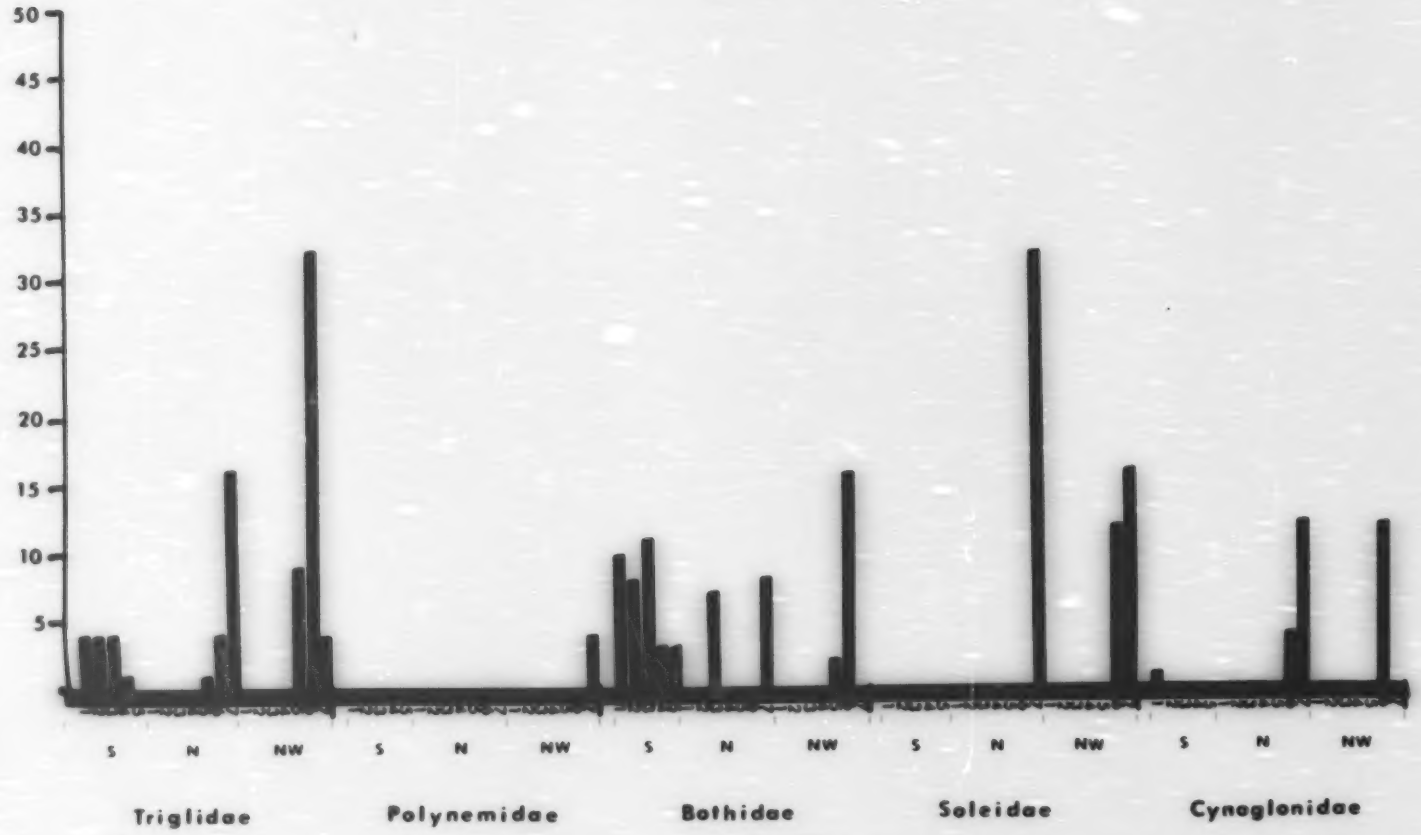

Figure 4.15c Numerical Abundance of Fish (20 min. trawl)

Figure 4.15d Numerical Abundance of Fish (20 min. trawl)

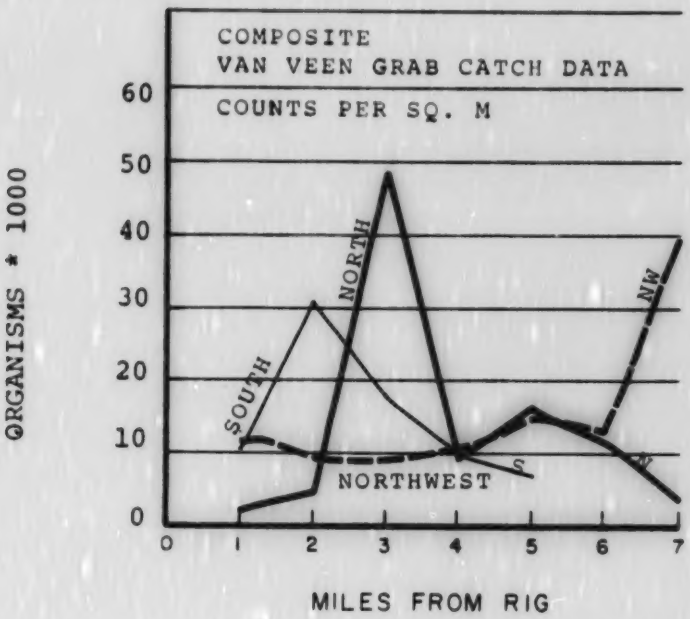

Figure 4.16 Composite Grab Catch Data

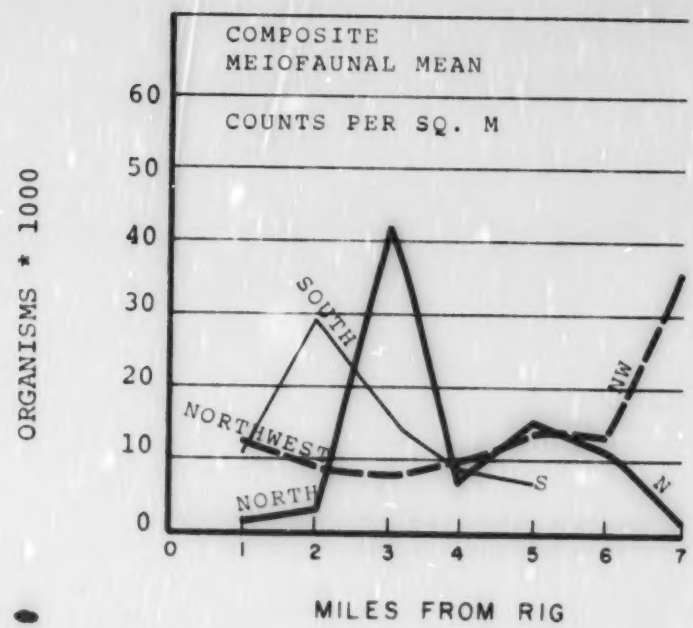

Figure 4.17 Composite Meiofaunal Mean Counts

to changes in salinity and sediment type, but intermediate stations are probably under the influence of some other limiting factor. Populations along the northwest transect were intermediate in numbers, but altered in population diversity and distribution. Again, it is probable that the extreme terminal stations of the transect exhibit alterations due to the influence of Timbalier Bay, but the middle stations are under the influence of other factors.

Without exception, megafaunal counts taken from grab samples were reduced as they approached the platform from all three directions, north, northwest, and south. A comparison of Figure 4.11 and Figure 4.18 suggests a general inverse relationship between megafaunal counts per square meter and the concentration (ppm) of sedimental hydrocarbons (CCl_4 extractables). Within the first three miles along the north transect, where the highest sedimental hydrocarbon concentrations were found (highest in all three transects) the lowest megafaunal (grab megafauna) counts of all transects were found. In the northwest transect, where sedimental hydrocarbons were present in intermediate amounts, observed grab megafaunal counts were found to be intermediate to the other two transects. Finally, along the south transect where sediment hydrocarbons were the lowest of the occupied transects, organism counts from grab samples were the highest.

4.1.3.2 Interpretation of Biological Catch Data

It must be recognized that the study area is located in a region of extensive oil production and that intensive activity preceded this study. Such activity included high noise and vibration levels associated with relief well drilling and control and containment of the spill (December 70 to March 1971) and removal of debris during and subsequent to that time. Extensive movements of surface vessels also occurred and there can be no doubt that these factors exerted some indeterminable degree of stress on the environment in the study area.

However, at the time the field sampling (on which most of the analysis in this report is based) was conducted, heavy activity was restricted to the immediate vicinity of the platform. Biological samples were taken at distances of one mile and more from the platform, a distance considered sufficient to buffer effects which might be attributable to such causes.

Examination of the catch data from trawl samples revealed a series of distinctly anomolous distribution and density patterns for the scavenger starfish, *Luidia clathrata*. As shown in Figure 4.20 distributional patterns are fairly similar along the northwest and south transects, but the distribution along the north transect

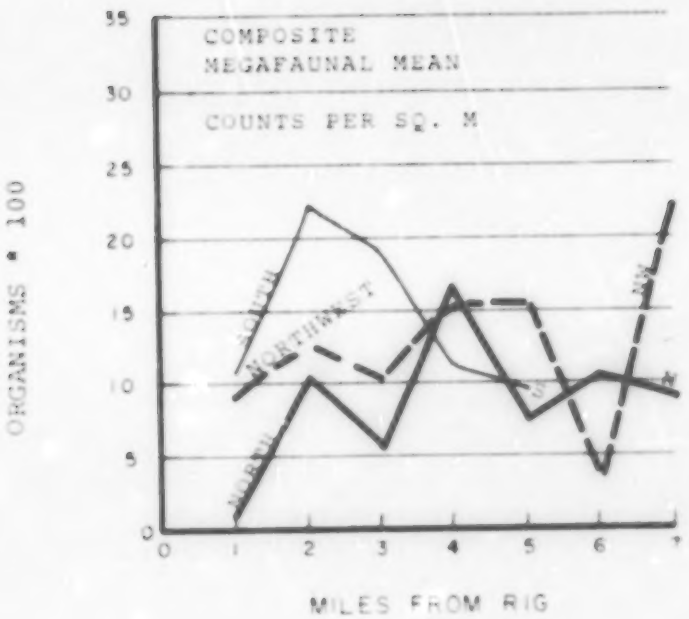
COMPOSITE
MEGAFAUNAL MEAN
COUNTS PER SQ. M
ORGANISMS • 100
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
SOUTH
NORTHWEST
NORTH
NW
MILES FROM RIG

Figure 4.18

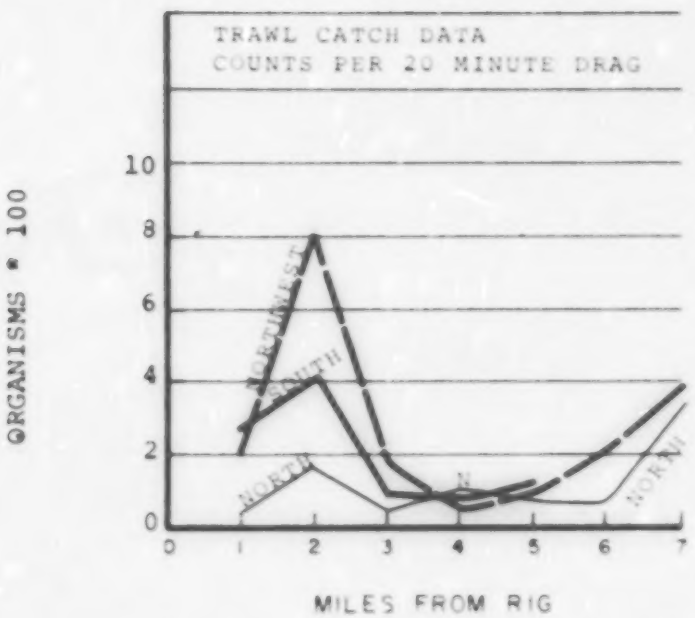
TRAWL CATCH DATA
COUNTS PER 20 MINUTE DRAG
ORGANISMS • 100
10
8
6
4
2
0
0
1
2
3
4
5
6
7
MILES FROM RIG
NORTHEAST
SOUTH
NORTH
NORTHWEST

Figure 4.19

is different. The numerical density of *Luidia* is highest along the northwest transect, with the numerical density along the south transect, although still high, moderately reduced. It was, again, along the north transect that anomolies occurred. For example miles 2 and 4 along the north transect exhibit the highest concentrations of *Luidia*, while mile 3 is totally devoid of the starfish. It is evident from Figures 4.20 and 4.21 that the numerical density of *Luidia* are being controlled by some external factor.

The conditions governing population density of *Luidia* and its closely allied cousin *Astropecten*, have been cited as principally salinity, sediment type, and availability of food. When the concentrations of *Luidia* are compared to the bottom salinity readings (Figure 4.22) several anomolies appear. Concentrations of *Luidia* along the south transect are very close to the normal expected populations for the biotope. Along the northwest transect, however, the numerical abundance far exceeds that expected, and along the north transect, the numbers are below the expected norm, in spite of an apparent compatibility to recorded salinities. Maloeuf (1937) suggests that the surface of starfish is freely permeable to water and any significant decline below some minimal figure in salinity will result in massive water uptake and death.

Loosanoof (1945) has shown that once above the minimum salinity range salinity ceases to be a significant factor in determining population density. In other words, drastic reductions in salinity will result in drastic reductions in population density, but drastic increases in salinity will have little or no effect upon increasing the size of the population.

It is of some interest to note that *Luidia* are frequently found along with the sand-dollar, *Mellita quinquiesperforata*, and seem to prefer the same biotopic conditions. The minimal salinities for *Mellita*, *Luidia*, and *Astropecten* have been studied and appear to fall into the 20 - 23^{0}/oo salinity range. As may be seen in Figure 4.21, the recorded salinities along all three transects fall well within the minimal tolerance limits of *Luidia*. The disjunctive distributional patterns, however, do not appear to reflect the salinity patterns.

Along the northwest transect, the numerical density far exceeds that expected, but the population is centered within the first four miles out from the rig. Beyond the 4 mile mark, *Luidia* all but disappear in spite of the fact that salinities are compatible. It would appear, then, that the concentration of *Luidia* within the four miles around Platform B and their peripheral scarcity are due to some factor other than salinity.

The numerical concentrations of *Luidia* along the North transect are the most disjunct found in any transect with a small peak

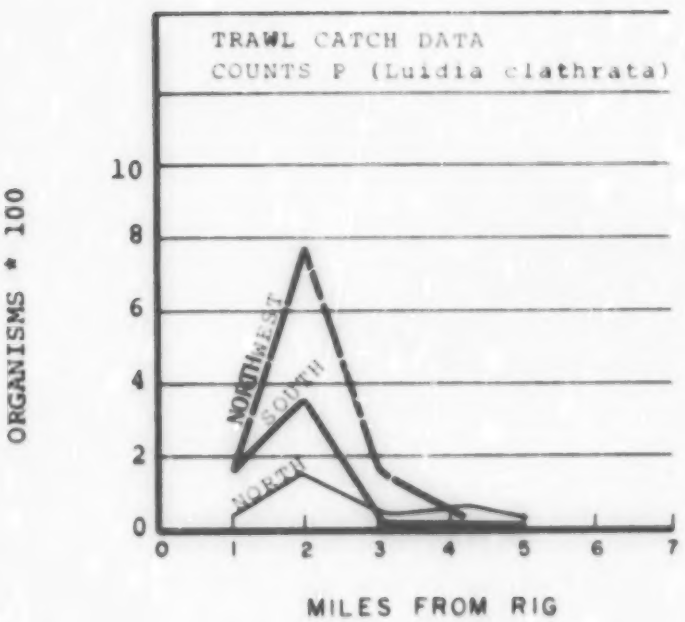
TRAWL CATCH DATA
COUNTS P (Luidia clathrata)
ORGANISMS * 100
10
8
6
4
2
0
0
1
2
3
4
5
6
7
NORTHWEST
SOUTH
NORTH
MILES FROM RIG

Figure 4.20

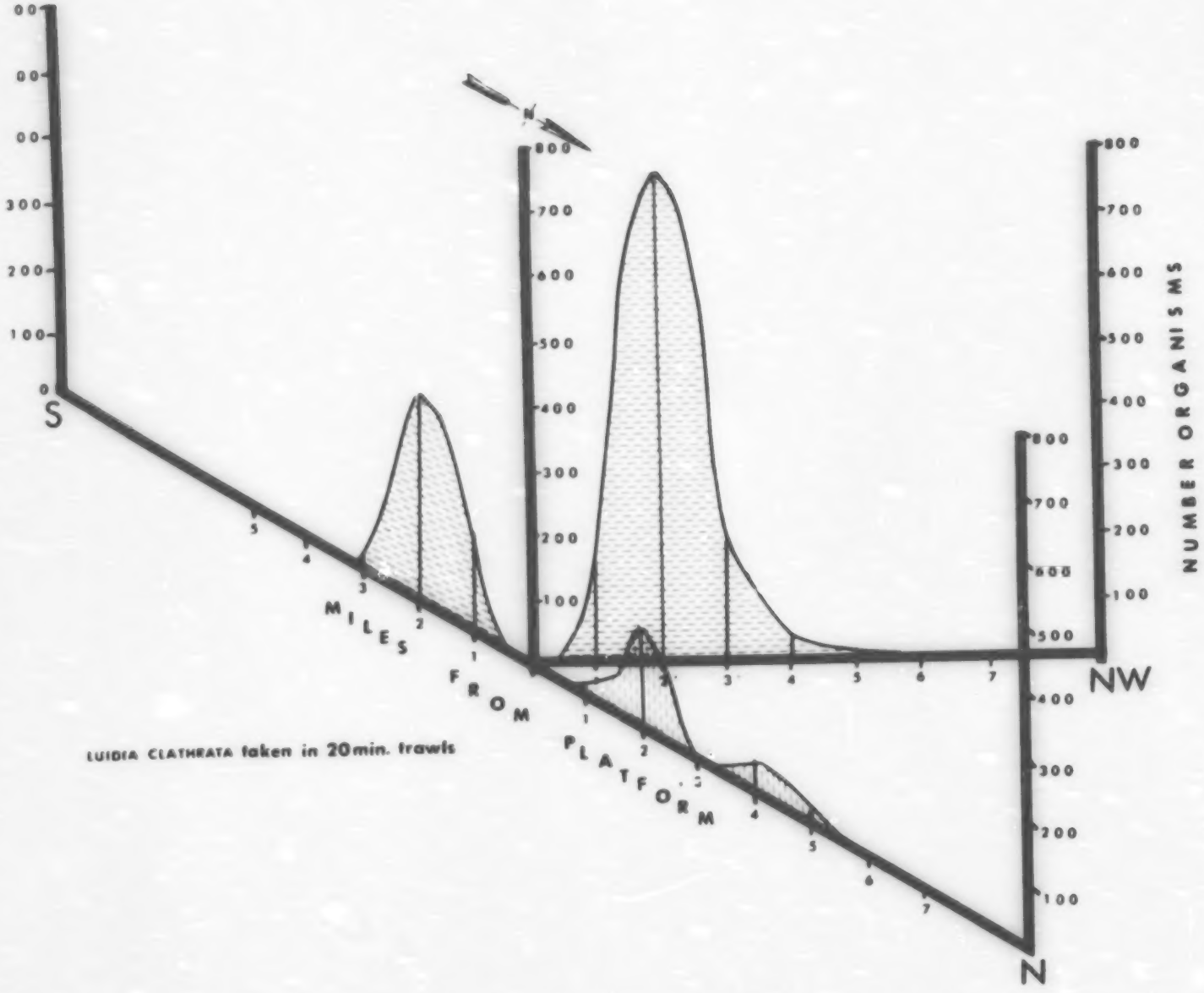

Figure 4.21 *Luidia clathrata* taken in 20 min. trawls

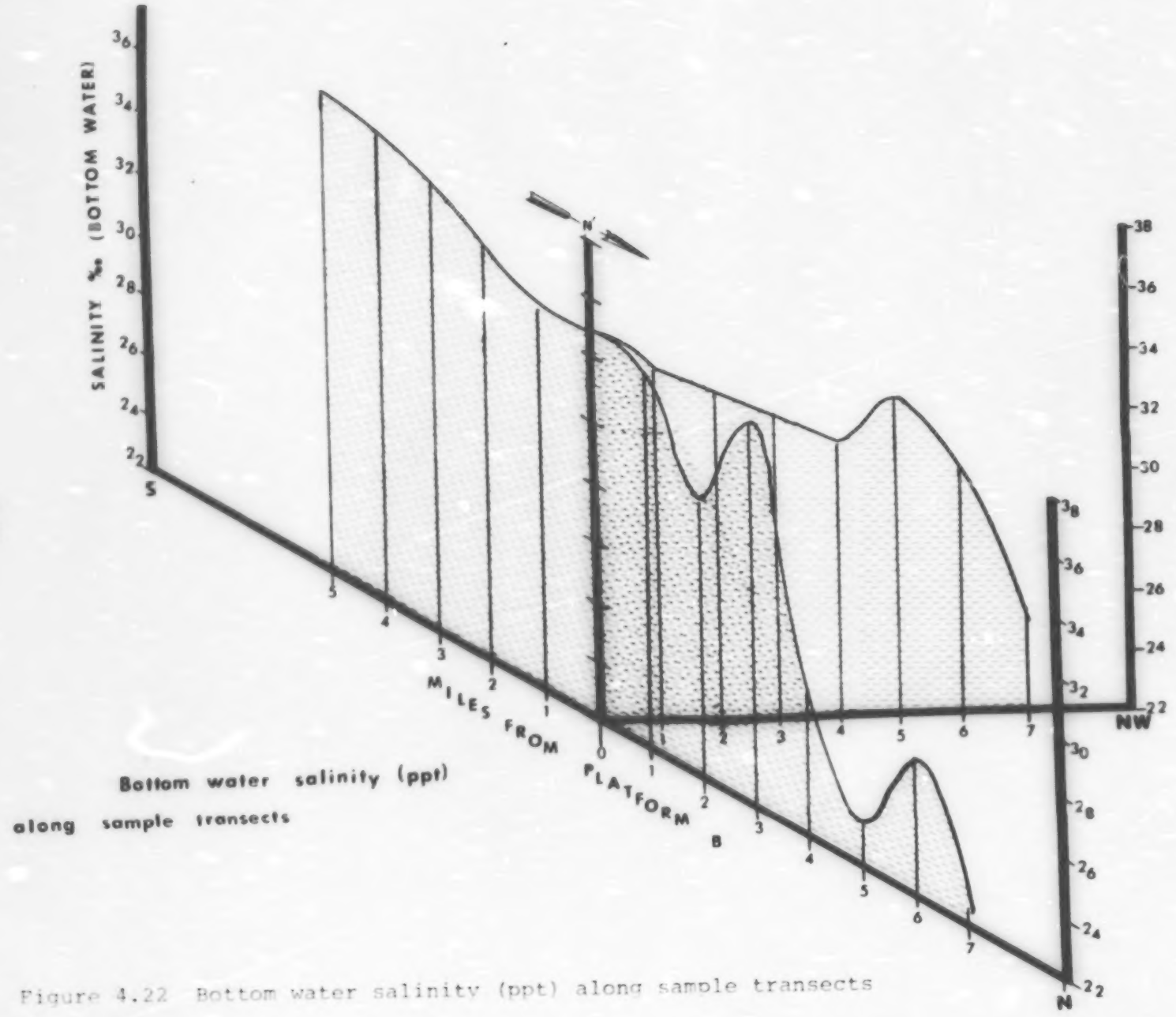

Figure 4.22 Bottom water salinity (ppt) along sample transects

2 miles north of the platform and a secondary peak 4 miles north. Between these two peaks, however, no *Luidia* were taken. At each of these stations, the recorded salinities were within the preferential ranges for *Luidia*. It would seem, therefore, that the populations along the north transect were being actively depressed by some agent and it is unlikely that the causal agent was salinity.

Hyman (1955) and MacGinitie and MacGinitie (1968) found that *Luidia* and *Astropecten* show a marked preference for sandy bottom sediments, but modifications of their tube-feet enable them to move about on silt and clayey-mud bottoms. The sediments in the immediate vicinity of the rig are silted mud with a moderate amount of sand deposition from the Mississippi delta mouth to the south and from the inshore bays to the north and northwest (see Section 2.0, this report). It appears, therefore, that sediment type is not a limiting factor on the *Luidia* populations.

The possible effect of food availability upon the *Luidia* distributions must be considered from two standpoints - (1) food selection based upon digestive characteristics of *Luidia* and, (2) the occurrence of preferential food sources *in situ*. The latter preferences are based largely upon the anatomical and behavioral characteristics of the starfish. *Luidia* is a scavenging carnivore, but it lacks the eversable stomach of the typical starfish. It also lacks any crushing or grinding mechanism. consequently, *Luidia* crawl about ingesting large quantities of sediment and benthic organisms and utilize all available organic material contained therein. The undigestable material is then regurgitated. The species for which *Luidia* has shown a preference include other echinoderms, especially ophiuroids, foraminfera, and molluscs. Analyses of stomach contents made by other investigators indicate a good preference of *Luidia* for gastropod molluscs over pelecypods, an almost direct contradiction to the preference seen in most other starfish. This stands to reason, however, since *Luidia* lack the eversible stomach necessary for the successful predation of bivalve pelecypods. The ability of *Luidia* and any other asteroid echinoderm to locate prey is dependent largely upon luck, but starfish possess a strong attractant mechanism whereby they are drawn to potential prey by concentrations of prey-emitted chemicals in concentrations as small as parts per billion. It has also been shown that increased amounts of the chemical will significantly increase the attraction of the starfish to the prey. Blumer (1969) has suggested that the longer chain, higher boiling aliphatic hydrocarbons mimic natural attractant stimuli.

The extreme abundance of *Luidia* along the northwest transect may possibly have been due to the attraction by ophiuroid echinoderms and gastropod molluscs. However at the time of the study population depletion as may be seen in Figures 4.14 and 4.22 resulted in concentrations of *Luidia* which were inversely proportional to the population densities of both ophiuroids and gastropods.

The presence of high concentrations of long chain aliphatics in the sediments along this transect add another possibility. If the theory proposed by Blumer *(ibid.*1969) is true, it is then possible that these starfish may have been drawn by false chemical stimuli. If such is indeed the case, then the low taxonomic diversity shown in Figure 4.13 for the northwest transect would appear to indicate a probable stress on the environment for the transect. The numerical resurgence along this transect (Figure 4.14) would then indicate the possible beginnings of a recovery phase.

North transect catch data exhibits an extreme anomoly. Both ophiuroid and gastropod populations show a numerical increase away from the rig, but the expected higher numerical concentrations of *Luida*, although minimally present at mile 2, fail to materialize (Figure 4.19). At the mile 3 station, the life zone is almost devoid of any species and *Luida*, ophiuroids, and gastropods are completely absent. Normal benthic inhabitants, such as polychaete annelids and the pelecypod molluscs, are also greatly reduced (Figure 4.14). A possible explanation for this apparent distribution anomoly may be found in Figure 4.5. Between the platform and the mile 3 station, the long chain aliphatic hydrocarbons were present in the sediments in quantities sufficient to be potentially toxic. These concentrations decrease sharply between the mile 3 and mile 4 stations. At about this same location, the incidence of aromatic hydrocarbons and a noticeable surface sheen were observed. The toxicity of aromatic hydrocarbons has been repeatedly documented and one would expect a depression in both numerical populations and taxonomic diversity. As may be seen in the Figures 4.13 and 4.14, this is indeed the case.

Stomatopod populations are another valuable indicator of differential environmental stress, since the adults are burrowing benthic organisms, while the larvae are planktonic in the water column above the bottom. The stomatopods (adult and larval forms) are almost uniformly absent from the north transect, as might be expected from the heavy hydrocarbon concentrations previously discussed. Along the northwest transect, however, the increase in numerical abundance of stomatopods is quite noticeable (Figure 4.14). It should be noted, however, that all of the stomatopods taken within 4 miles of the rig were larval and no evidence of either settling of larvae or indigenous adults in the sediments could be found. This is in contrast to the large numbers of adults found in the sediments farther out along the transect. The absence of stomatopods in the sediments within 4 miles is a strong indication of severe environmental stress in the area, since they occur in all surrounding sediments and are quite numerous beyond the "sterile" zone. The presence of larval stomatopods in such large quantities in the water column above these "sterile" sediments, however, is an indication that this portion of the transect is normally subject to larval dispersal and repopulation. The failure of successful repopulation evidenced by the absence of adult stomatopods in these sediments indicates a continuing environmental stress in the sediments. The presence of

stomatopod larvae, however, attests to the potential recovery possibilities, since the low-boiling aromatic hydrocarbons - the toxicants that would be present in the water-column - are particularly toxic to planktonic larvae. These toxicants were therefore reduced or absent.

Pelecypod molluscs were not abundant along any of the north and northwest transects but were nominally present along the south transect stations. The predominant pelecypod near the rig was *Corbula swiftiana*. Farther out along the south transect, however, *Corbula* populations were gradually replaced - first, by *Nuculana* and then by *Tellina* (see Appendix II). This represents a fairly normal faunal succession from clay to sandy bottoms.

Along the northwest transect, the pelecypod populations were uniformly low (Figures 4.3 and 4.14), but it appears the tendency was for *Tellina* to increase as the transect neared shore. Along the north transect, there was essentially no pelecypod population near Platform B (Figure 4.14), but the numbers tended to increase with increasing distance from the platform. At miles 3, 4, and 5, the predominant pelecypods were *Tellina*, with the population peak at mile 4. Beyond the 5 mile station, the *Tellina* populations appear to be replaced by *Nuculana* and *Mulinia*. Both of these latter species are euryhaline organisms with a habitat preference for sandy-mud bottoms and are characteristic of inshore and bay entrance biotopes.

The significance of the pelecypod populations is related to the habitat selection and behavioral feeding responses characteristic of *Tellina*. *Tellina* maintains a definite sphere of influence and, when crowded, will migrate to less dense areas or, if unable to do so, will exhibit growth anomolies. The *Tellina* is typically a sandy bottom inhabitant but will move into partial mud bottoms when forced to do so. A fairly hardy organism, the *Tellina* will actively move away from its neighbors whenever the population density is lessened in an adjacent region.

Since normal concentrations of *Tellina* have been shown to be approximately 250/m^2 and, since the numbers of *Tellina* collected along the north transect fall on or above this value (while numbers of other species are reduced), these numbers would tend to indicate that *Tellina* had migrated into the area. This possibility is also supported by the fact that the substrata in which they were found was mud or sandy mud, a substrata that is not one of preference for *Tellina*. One would normally expect to find *Nuculana* or *Mulinia* to be the predominant organism in this area.

This was the case at the extreme end of the transect indicating the *Mulinia* was the normal inhabitant. For some reason, it had disappeared and been replaced by *Tellina*.

Significant conclusions regarding the fish populations in and around the study area were not possible to derive because of

their natural mobility and seasonality, and because of the possible impact of noise and activity levels on the populace. It is of interest to note, however, that those areas along the transects which theoretically showed environmental stress exhibited fish populations lower than areas showing lesser stress. The area immediately around the platform was almost devoid of fish (Figure 4.15).

It has been established that various petroleum fractions are, in general, toxic to pelagic marine species. Because the investigation of sediment hydrocarbons revealed relatively high concentrations, and such concentrations corresponded with the location of observed surface sheens, it was hypothesized that significant quantities of hydrocarbons would be found throughout the water column in these locations. This resulted in the decision to conduct histological examinations of fish taken from the study area; with such examinations validated with control specimens taken from Aransas Bay, Texas; an area comparable, both physically and biologically, to the study area.

4.2 Histological Comparisons of Branchial Gill Filaments Taken From Fishes

4.2.1 Introduction

In higher fishes, the gill pouch is a passageway from the pharynx directly to the outside through gill slits or through a gill chamber covered by the operculum. The mucous membranes of the anterior and posterior walls of each gill pouch are raised into a number of horizontal ridges called branchial filaments. The branchial pouches consist of an arch bearing the posterior filaments of one pouch and the anterior filament of the next. (Lagler, Bardach, and Miller, 1962). The fundamental histological structure of branchial filaments consists of a low, single-layered epithelium surrounding the basic filament. The blood vessels are lacuna (round) or sinusoidal (irregularly-shaped) in nature, and are supported (kept open) by connective cells called "pillar cells." Mucous-secreting cells are common and are scattered along the filament. (Patt and Patt, 1969). Covered pseudobranchs contain many acidophilic secretory cells which are presumed to be the sites of production of carbonic anhydrase-like enzymes. These acidophils are located on the side of the branchial filament supplied by afferent capillaries (Andrew, 1959). In addition, those fish adapted to sea water possess an "excretory vesicle" at the free surface of the epithelial cell (Bevelander, 1935).

4.2.2 Experimental Procedure

4.2.2.1 Specimen Selection

Specimens were collected from three transects radiating outward from Shell Platform B, Block 26. The transects ran south, north, and northwest from the platform. Representative specimens from seven species of fish were randomly selected from each transect station near the platform. Thin section tissue slides of the first gill arch from each specimen were prepared using mictrotome techniques and a paraffin mount. The preparations were stained with Delafields Hematoxylin and counterstained with Eosin. These histological slides were compared with preparations of similar tissue taken from specimens from a control location (Aransas Bay, Texas).

4.2.2.2 Control Specimens

Gill filaments were considered to be of greatest importance since they are sensitive to environmental stress. Table 4.1 lists the species and place of capture of the test and control specimens examined.

The specimens from the south transect exhibited no apparent abnormal loss of gill tissue compared to control specimens. Certain abnormalities were found to occur, however, in fish from the north and northwest transects. These abnormalities are illustrated in Figures 4.23A and 4.23B.

The specimen from SPNW-17 (161A) *Anchoapaetta*, showed a loss of: (1) epithelial, (2) mucous-secreting cells and (3) some acidophils (Figure 4.24A). "Normal" branchial filaments are ragged in appearance, as is shown in the control specimen (Figure 4.24B). The control exhibits loosely arranged cells between each filament. In the specimen from the spill zone these cells are absent or significantly reduced in numbers. The loss of these cells is termed "sloughing" and could result in certain physiological changes discussed later. The remaining cells in the damaged filament appear to be slightly swollen and caused the "blurred" photographic response.

Specimens of *Micropogon* (Figure 4.25A,B) exhibited similar cellular alterations as those found in *Anchoapaetta*. Again, the tissue from the control fish was normal with a typical ragged appearance (Figure 4.25A). However, the specimen from the spill area (SPNW-16, sample no. 154B) exhibited the following abnormalities: (1) swollen branchial filaments, (2) definite loss of epithelial cells and (3) noticeably fewer mucous cells (Figure 4.25B). This loss of cells was not as pronounced as that found in *Anchoapaetta*

Table 4-1
Test Specimens

SPECIES	COLLECTION SITE
Ancylopsetta quadrocellata	Aransas Bay SPNW-17-161A
Micropogon undulatus	Aransas Bay SPNW-16-154B
Etropus crossotus	Aransas Bay SPN-8-144B
Prionotus tribulus	Aransas Bay SPS-1-36
Chloroscombrus chrysurus	SPN-8-114
Chaetodipterus faber	SPN-1

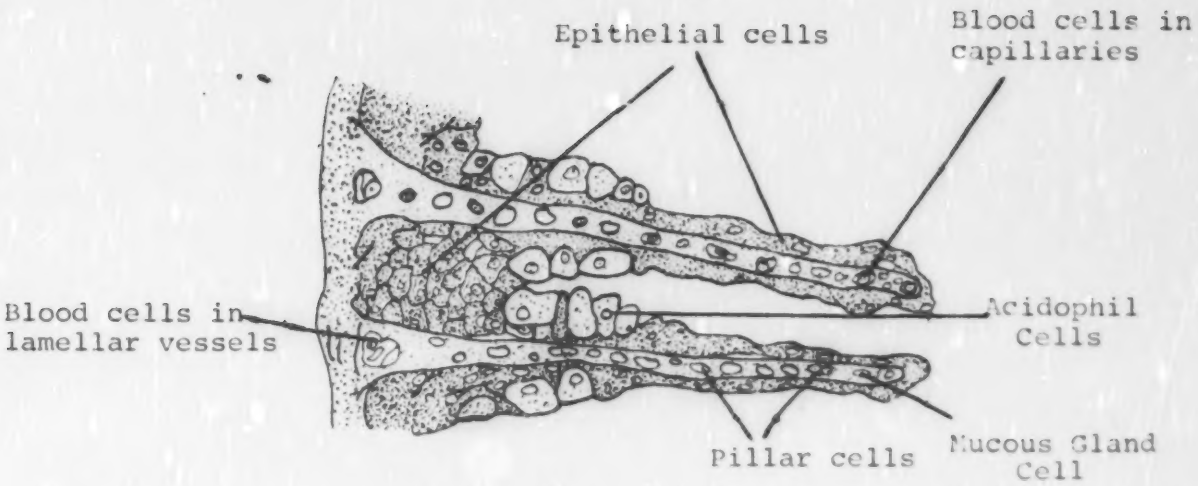

Figure 4.23A Typical Telcost Branchial Filament

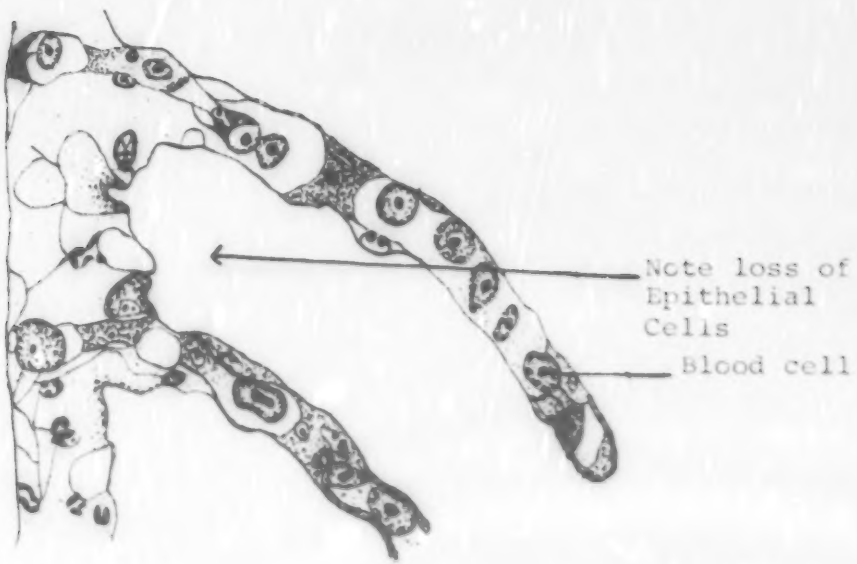

Figure 4.23B Example of Branchial Filament which has lost some tissue

Figure 4.24A Normal branchial filament from *Ancylopsetta*.

Note cells between each filament(arrows), mucous cells (M), pillar cells (P) and acidophilis (A).

Figure 4.24B Branchial filament from *Ancylopsetta* taken near Shell Platform.

Note loss of epithelial cells (sloughing) between the filaments, giving a rather "clean" appearance. Also, note swollen Filaments (S).

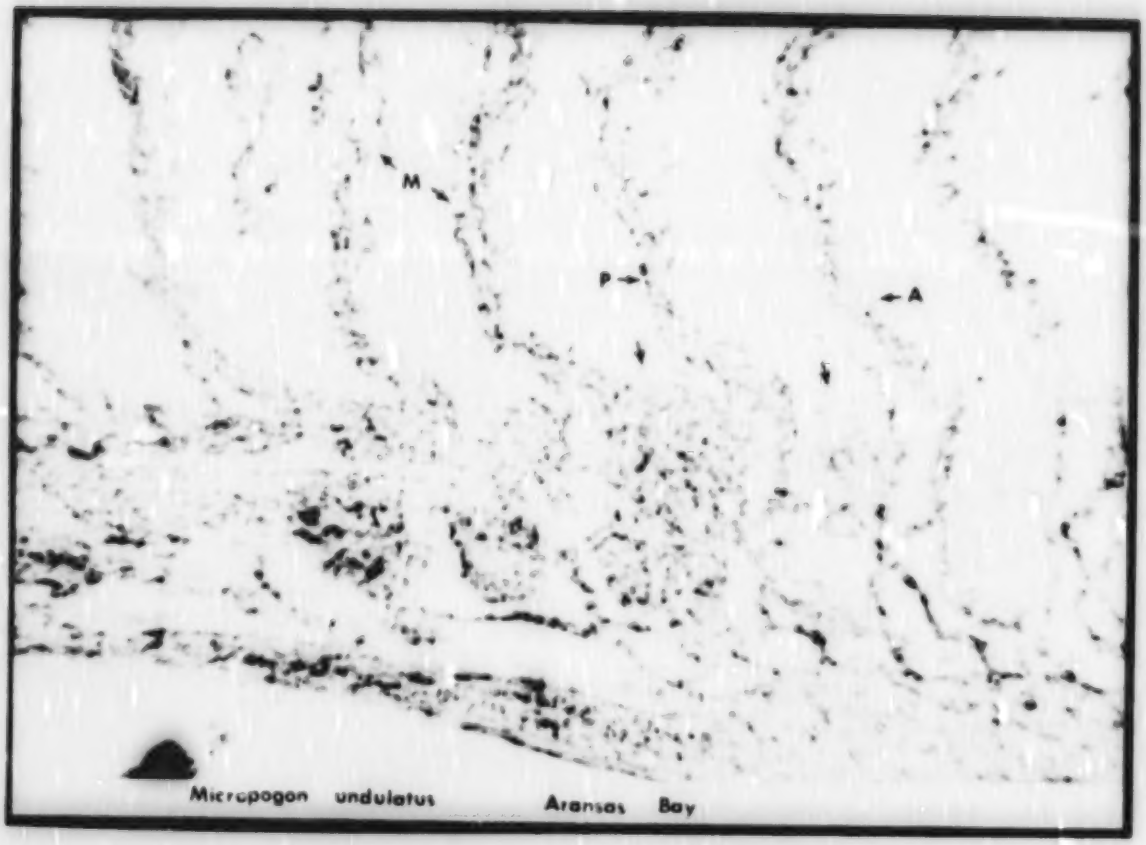

Figure 4.25A Normal filaments from *Micropogon*. Structures seen are identical to those in Fig. 2A. Epithelial cells (arrows), mucous cells (M), pillar cells (P) and acidophils (A).

Figure 4.25B Note washed-out appearance due to sloughing (arrows) and swollen filaments (S).

(Figure 4.24B). *Micropogon* is a fast-swimming, shallow or mid-water fish capable of moving away from adverse conditions. *Anaylopsetta* is a slow-swimming bottom-fish easily affected by environmentally induced physiological stress. The loss of tissue was evident in both specimens.

Another bottom-dwelling fish, *Eutropus grossotus*, was examined from Station SPN-8 (sample 144B). A control specimen of this species from Aransas Bay showed no gill damage (Figure 4.26A,B). Swelling coupled with loss of epithelial cells was also observed. Mucous cells were present in reduced numbers and the filament had a "smeared" appearance as though it were soft from degeneration.

A specimen of *Prionotus tribulus* was taken from the south transect of the oil spill area. No pathological alterations were observed in histological preparations from this specimen (Figures 4.27A,B).

Finally, specimens of *Chloroscombrus* (Figure 4.23A) and *Chaetodipterus* (Figure 4.28B) were examined histologically and found to be normal; with the possible exception of slight swelling and minor epithelial sloughing in *Chloroscombrus*.

4.2.3 Discussion

Specimens 114 A and 114 B were taken from station SPN-8 located 3 miles north of the Shell Platform B in the wake of the oil sheen. Spill data indicated that the oil was being redispersed to the water column from sediments in this area hence, bottom swimming fish would be in contact with these redispersed petroleum fractions. Histological preparations from the gills of these two specimens were compared with those of the same species taken from Aransas Bay, Texas (control specimens). Gill filament epithelium from the fishes taken near the Shell Platform had sloughed away in several areas.

The filament taken from *Eutropus grossotus* in Aransas Bay was intact and showed no apparent sloughing. Preparations from fish gills near the Shell Platform exhibited a definite loss of acidophilic and mucous cells. Control and experimental specimens of *Micropogon undulatus* (154B, from station SPNW-16, 4 miles northwest of the platform in the vicinity of the oil sheen and a specimen from Aransas Bay) yielded similar data; a loss of epithelial tissue; however, other cell losses from this specimen were not evident and the control specimen was unaltered. Specimens examined from the south transect near the Shell Platform where there was no evidence that redispersion was occurring showed no apparent cell loss.

The alterations of branchial filaments discussed herein may produce certain physiological malfunctions. The loss of sufficient

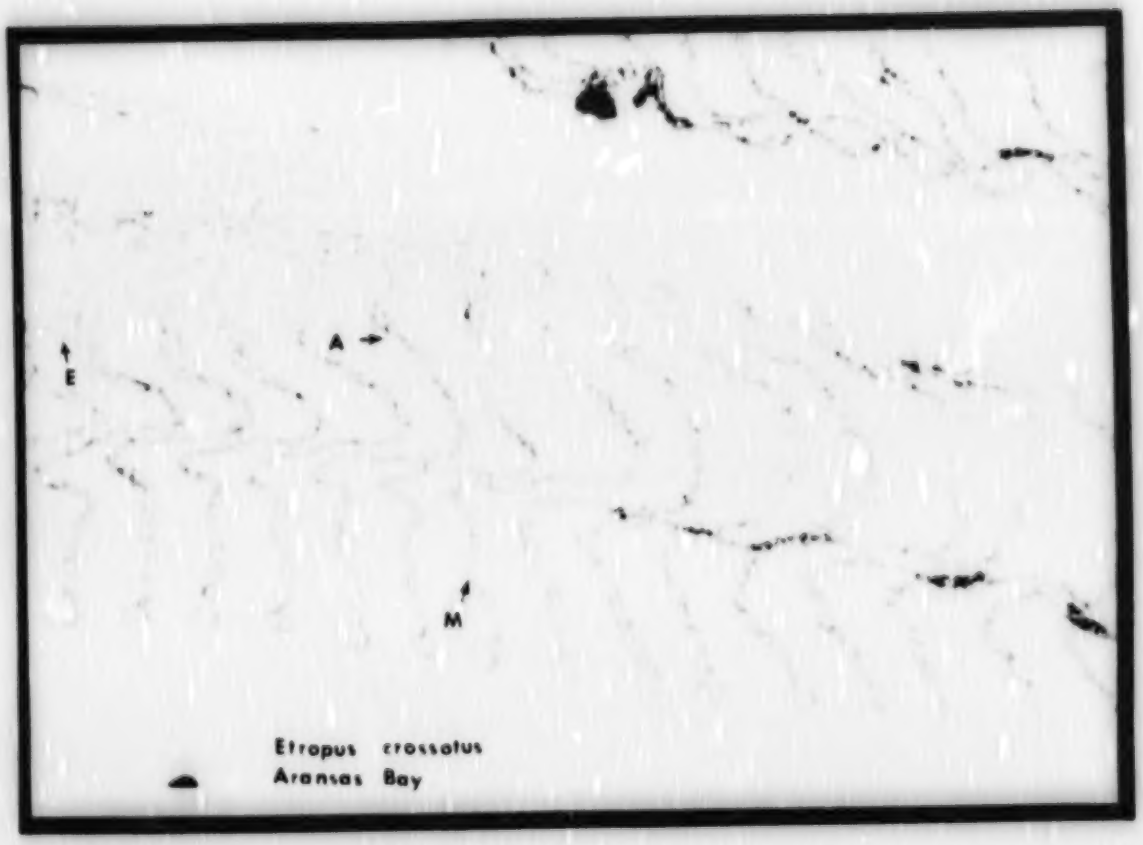

Figure 4.26A Normal *Etropus* from Aransas Bay.
Note many mucous cells (M), acidophils (A),
Epithelium (E).

Figure 4.26B Shell sample *Etropus*. Note swelling (arrows), fewer mucous cells (M).

Figure 4.27A *Prionotus* - South transect from shell platform. Acidophils (A), mucous cells (M), Pillar cells (P) - intact.

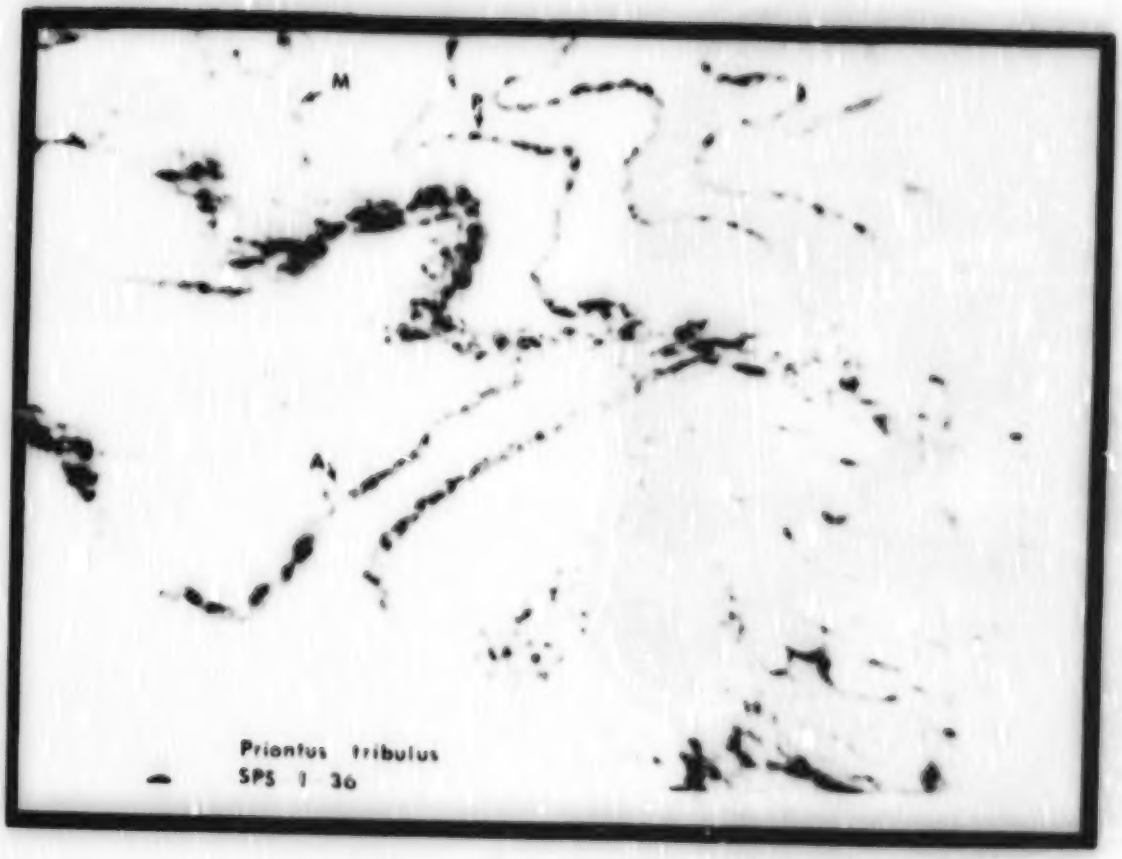

Figure 4.27B *Prionotus* - Aransas Bay, Acidophils (A), mucous cells (M), pillar cells (P) - all intact.

Figure 4.28A *Chloroscombrus* - South transect. All cells intact. Acidophils (A). Mucous (M), and Pillar cells (P).

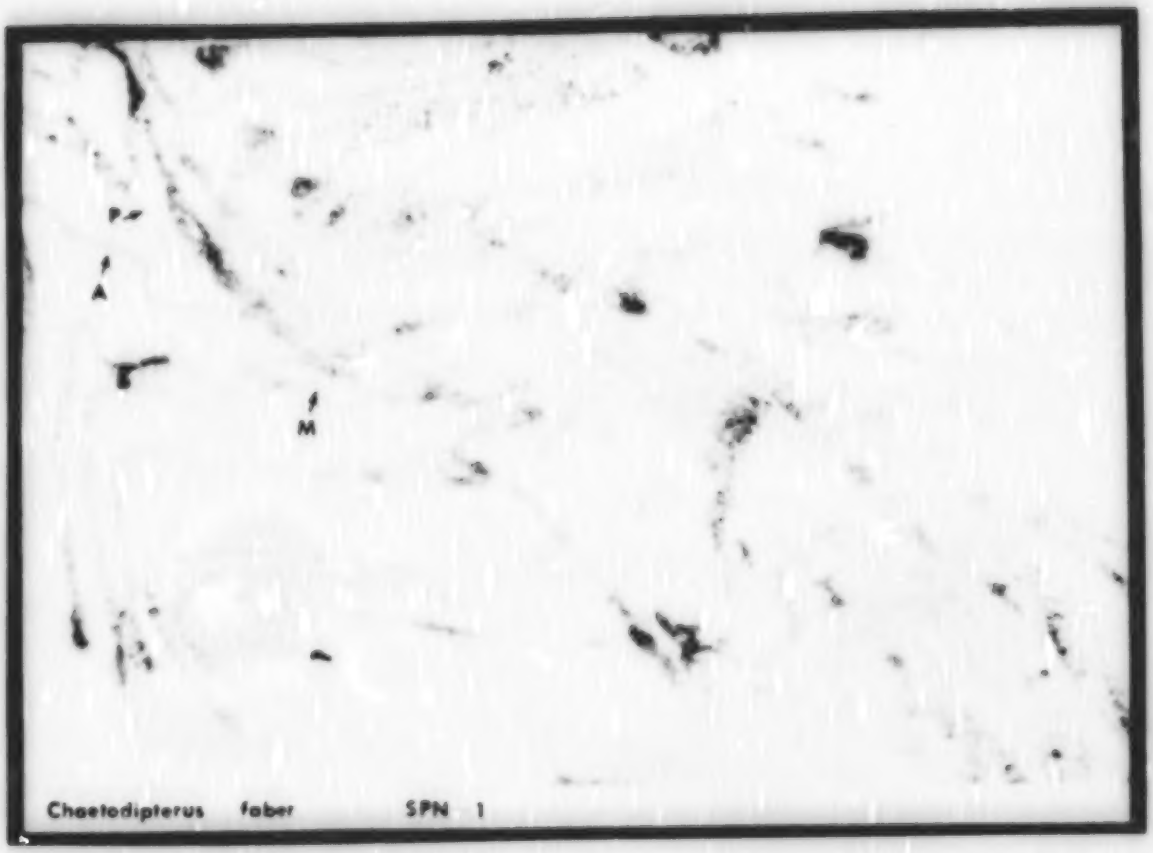

Figure 4.28B *Chaetodipterus* - South transect. All cells intact. Acidophils (A), Mucous (M) and Pillar (P)

acidophils will reduce the production of carbonic anhydrase-like enzyme (secreted by these cells). This enzyme deficiency may lead to pH changes in the blood and tissue fluids (acidosis or alkalosis) through a reduction in the rate of dissociation of carbonic acid into CO_2 and hence a malfunction of the blood-buffer system.

Loss of mucous cells may result in the clogging of the filaments with detretus. Resultant irritation of the filament may produce epithelial sloughing as that seen in test specimens.

These data are not conclusive with regard to the impact of petroleum fractions on pelagic megafauna because of the migratory nature of these animals; however, the observed damage raises certain critical questions which deserve further investigations under controlled laboratory conditions. Laboratory studies using sublethal quantities of oil and histological techniques should be incorporated into studies on the fate and effects of marine oil spills. Standard T_LM tests coupled with autopsies of terminal animals and histological procedures are also indicated. Such studies would establish direct cause-effect relationships and establish correlations with such alternatives as viral, fungal, bacterial or parasital contributions (including possible inducement by effects of oil).

5.0 Conclusions

From the data acquired and the analyses conducted, a number of meaningful conclusions can be drawn. From these conclusions and experience gained in the performance of this study, the following can be accomplished:

- Achieve better understanding of the specifics of the fate and effects of the incident under study;
- Extend the body of knowledge of the fate and effect of such spills, in the areas affected, and, in the Marine Environment as a whole;
- Enhance the value of future studies of this nature by refinement of techniques and procedures.

Analysis and evaluation of data, acquired during this study on the fate and the effects, of the Shell incident at Platform B, Block 26, has been discussed in Section 4.0 of this report. Specific conclusions reached in the performance of the analyses and data gathering are summarized in this section.

5.1 Fate of Spilled Oils

Data presented in Section 4.1 of this report suggests that water-dispersable fractions (probably aromatic compounds) from the crude oil spilled were transported through the water column and deposited in sediments at least to the observed depths of sixty feet (60'). It has also been established that these deposits become redispersed into the overlying waters. Correlation has been established between the locations of these sedimentary deposits and the surface locations of slicks and sheens throughout the areas of migration of the spill oil.

The sedimentary deposits of crude oil contained significant quantities of Carbontetrachloride Extractable Hydrocarbon (CCl_4 extractables) as represented by the Aliphatic Hydrocarbons. In fact, sediments near the platform (source of the spill) were found to contain in excess of 4.5 ppt compared to about 300 ppm one mile from the platform and between 50 and 100 ppm at a distance of four miles. However, in the area of an observed sheen, as far as 7 miles from the source, sedimental CCl_4 extractables were again found at levels of concentration in excess of 300 ppm. These data may be influenced by oil dispersants to the extent dispersants were introduced during the spill.

The water dispersable Hydrocarbons were probably aromatic compounds, highly soluble in salt water and therefore more biologically accessable. Although representing only a small percentage of the released aromatics, the majority of which dissipated prior to settlement, the apparent cycling from the water column to sediments and back to the water is potentially damaging to the ecosystem.

Benthic populations may be damaged by these transient materials which are redispersable and may not be detectable within brief periods after deposit. Similarly, pelagic and benthic organisms may be adversely effected by these processes of free movement of both the aliphitics and water dispersable hydrocarbons. Both are potentically toxic to the pelagic and benthic communities.

5.2 Effect of Spilled Oil

Assessment of the effect of the spilled oil was based on an evaluation of the sampled (or observed) ecosystem; a comparison of species diversity, and distribution; and examination of specimens, both in the field and in the laboratory. To the fullest extent possible applicable background data available in literature and data acquired during earlier studies in the area of Platform B (December 1970 studies) have been utilized in the studies reported herein. The results of these investigations and the conclusions reached are summarized in this Section.

5.2.1 Species Diversity

Data yielded by Van Veen grab sample resulted in little or no correlation of the numbers of species present with any other parameters. The single exception of this was a direct, although poorly defined, relationship between dominance diversity and hydrocarbon concentrations in sediments. This is reflected by the increased, simple diversity of megafauna found in samples in the South and Northwest transect over the North transect which corresponded to the direction of movement of the spill.

5.2.2 Distribution of Fauna (Meiofaunal and Megafaunal)

Faunal counts from bottom sampling were low at and immediately around the rig with 13,000 per square meter of less within a one mile radius. Between one and two miles, general

numerical increases were found. In the South transect, the highest faunal count of 32,000 per square meter occured at the two mile mark. In the North transect, a high count of 48,000 per square meter was found at the four mile mark, with a steady and marked decrease at greater distances. In the Northwest transect, intermediate numbers were encountered, however, distinct alterations in population diversity and distribution was noted.

Grab sample megafaunal counts significantly diminished from all directions as they approached the platform. A generally inverse relationship between megafaunal counts per square meter and the concentrations (ppm) of sedimental hydrocarbons (CCl_4 extractables) was found. Within the first three miles along the North transect where the highest sedimental hydrocarbon concentrations of the three transects were found, the lowest grab megafaunal were recorded. In the northwest transect, where sedimental hydrocarbons were present in the intermediate amounts, grab megafaunal counts were intermediate to the other two transects. Finally, along the south transect where sediment hydrocarbons were the lowest, organism counts were the highest.

Examination of trawl sample catch data revealed distinctly anomolous distribution and density patterns for the scavenger starfish, *Luidia Clathrata*. Distribution patterns remained similar in the south and northwest transects; with higher densities in the northwest and moderately reduced densities in the south. However, in the north transect significant anomalies occur. These anomalies; typified by the highest concentrations at miles 2 and 4 with a population void at mile 3, establish that concentrations are being controlled by some external factor.

Analyses of these phenomena reveal that the relatively uniform concentrations along the south transect are very close to the normal expected populations. Along the northwest transect, the density far exceeds that normally expected while the numbers encountered in the north transect fell below the normal population. Because salinity is known to affect the density of *Luidia*; an analysis was conducted and the recorded salinity ranges of all areas studied were found to fall within the tolerance range of the *Luidia*. This factor was thus dismissed as a possible cause of the anomalies.

Since salinity was not determined to be the depressant, other possible causal factors were considered. The bottom sediments in the study area were found to be silted mud with a moderate amount of sand deposition; again within the tolerance, range of the *Luidia*. This was, therefore, also discounted as a limiting factor on the populations.

The possible effect of food availability was considered in terms of food preference as opposed to the occurrence of preferential foods in the sampling area. The *Luidia* feeds by ingesting large quantities of sediment and benthic organisms and utilizing all available organic material so ingested; subsequently regurgitating the undigestables. Preferences include other echinoderms, especially ophuiroids, foramenfera, and molluscs; with a sharply defined preference for gastropod molluscs over pelecypods. Although primarilly locating prey by chance encounter in its foraging; prey-emitted chemicals appeal to a strong attraction mechanism and entice the *Luidia* to the better feeding grounds. An extension of this concept opines that longer chain, higher boiling aliphatic hydrocarbons mimic natural attractant stimuli and thus attract the *Luidia* to areas of higher than normal hydrocarbon concentrations.

Based on these premises, an evaluation of the impact of food availability on areal densities was made. This evaluation led to the following conclusions:

1) The extreme abundance of *Luidia* along the northwest transect is inversely proportional to the population densities of both ophiuroids and gastropods. The presence of high concentrations of long chain aliphatics in the sediments along this transect was revealed by sampling thus, based on the premise that *Luidia* are attracted by prey-emitted chemical stimuli which is mimicked as false chemical stimuli by long chain aliphatics, the low taxonomic diversity for the northwest transect would appear to indicate an oil induced stress on the environment for the transect. The numerical resurgence at greater distances along this transect would then indicate the beginnings of a recovery phase.

(2) North transect catch data exhibits an extreme anomaly. Both ophiuroid and gastropod populations show dramatic increases at greater distances from the rig, but the expected higher concentration of *Luidia*, although minimally present at mile 2, fails to materialize. At the mile 3 station, the life zone is almost devoid of any species and *Luidia*, ophiuroids, and gastropods are completely absent. Normal benthic inhabitants, such as polychaete annelids and the pelecypod molluscs, are also greatly reduced. A possible explanation for this depressed state may lie in the concentrations of long chain alipatic hydrocarbons in the sediments; quantities sufficient to be potentially toxic. These concentrations decrease sharply between the 3 and 4 mile stations where the incidence of aromatic hydrocarbons and noticeable surface sheen were observed to terminate. Because the toxicity of aromatic hydrocarbons has been established a depression in both numerical populations and taxonomic diversity can be expected.

3) Stomatopod populations were also evaluated and found (in both adult and larval forms) almost uniformly absent from the north transect. This is as expected in view of the heavy hydrocarbon concentrations. Along the northwest transect, however, the increase in numerical abundance of stomatopods is quite marked. However, all stomatopods taken within 4 miles of the rig were larval and no evidence of either settling of larvae or indigenous adults in the sediments could be found. This is in contrast to the large numbers of adults found in the sediments farther out along the transect. The absence of stomatopods in the sediments within 4 miles is a strong indication of severe environmental stress in the area. The presence of larval stomatopods in such large quantities in the water column above "sterile" sediments is an indication that the area is normally subject to larval dispersal and repopulation. The failure of successful repopulation evidenced by the absence of adult stomatopods indicates a continuing environmental stress, although the presence of larvae attests to a potential recovery.

4) Pelecypod molluscs were not abundant along any of the north and northwest transects but were nominally present to the south. The predominant pelecypod near the rig was *Corbula swiftiana*. Farther out along the south transect, however, *Corbula* populations were gradually replaced - first, by *Macula* and then by *Tellina*.

Along the northwest transect, the pelecypod populations were uniformly low with a tendency for *Tellina* to increase nearer shore. Along the north transect, there was essentially no pelecypod population near Platform B with increasing numbers farther from the platform. At miles 3, 4, and 5, the predominant pelecypods were *Tellina*, with replacement by *Nassarius* and *Mulinia* beyond the 5 mile point.

Because the major anomalies evolved around the *Tellina*, analysis involved its habitat selection and behavioral feeding responses. The *Tellina* maintains a definite sphere of influence and, when crowded, will migrate to less dense areas. Typically a sandy bottom inhabitant, the *Tellina* will move into partial mud bottoms when forced to do so. Normal concentrations of *Tellina* have been shown to be approximately 250/m^2. Since the numbers collected along the north transect were equal to or greater than normal (while numbers of other species are reduced), the conclusion can be drawn that *Tellina* had migrated into the area. This conclusion is also supported by the fact that bottom sediments were mud to sandy-mud, not a preferred habitat of the *Tellina*. Thus *Tellina* replaced the *Macoma* or *Mulinia*; normally the predominant organism in the area.

5) Significant conclusions regarding fish populations were not practical because of their natural mobility and seasonality.

However, those areas along the transects in which other evidence showed environmental stress exhibited very low fish populations, while the area immediately around the platform was almost devoid of fish.

5.2.3 Histological Data

On the basis of the significant evidence resulting from the analyses previously discussed, it was concluded that an oil-induced stress of unknown origin existed in the environment particularly in the vicinity of oil sheens at 4 to 6 miles north and northwest of the platform. To test this conclusion, histological examinations were conducted to determine if fish taken from the vicinity of the oil sheens would show signs of gill damage. A series of histological studies were performed on the gills of different species of fish in both a control group taken outside the spill area and on specimens captured at the sampling stations located at the scene of the spill. The gill filaments of fish are considered important because they are sensitive to contaminants and thus are reliable indicators of environmental stress. Thin section tissue slides were made of randomly selected specimen fish collected along the three transects.

Specimens examined from the south transect exhibited no abnormalities when compared to control specimens. Tissue slides of fish specimens from the north and northwest transects, however, showed loss of cells, "sloughing" and swollen branchial filaments, symptoms of environmental stress. Because of the direct correlation between sedimental hydrocarbon content and locations of observed surface oils and the locations where test specimens were taken; it is highly probable that the indicated environmental stress is the result of toxic hydrocarbon fractions within the water column.

6.0 Bibliography

In the performance of sampling and analyses, and in the compilation of this report, numerous findings and data from previous publications have been used. Those publications are listed, alphabetically, in this section.

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